THE UNIVERSITY OF ALBERTA

FORAMINIFERA OF THE BEARPAW FORMATION, CENTRAL SOUTHEASTERN ALBERTA

by

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A THESIS

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Foraminifera of the Bearpaw Formation, central southeastern Alberta", submitted by M. M. Given, B. Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Thirty-six species of Foraminifera are described from the Late Campanian Bearpaw Formation of central southeastern Alberta. Twenty-three species are referred to previously known taxa and one possibly new genus has been tentatively designated as ?Valvulineria. The arenaceous forms are dominant numerically with seven families being represented by 20 species. Nine calcareous families are represented by 16 species. The most important of these families are the arenaceous Astrorhizidae, Saccamminidae, Lituolidae and Ataxophragmiidae; and the calcareous Turrilinidae, Discorbidae and Anomalinidae.

The foraminiferid genera (with the number of species described) occurring in the Bearpaw Formation are: *Bathysiphon*, 1; *Hippocrepina*, 1; *Saccammina*, 5; *Ammodiscus*, 1; *Haplophragmoides*, 6; *Textularia*, 1; *Trochammina*, 1; *Verneuilina*, 1; *Verneuilinoides*, 3; *Quinqueloculina*, 2; *Dentalina*, 1; *Neobulimina*, 1; *Praebulimina*, 2; *Eoeponidella*, 2; *Valvulineria*, 2; *Heterohelix*, 1; *Globigerinelloides*, 1; ?*Cassidella*, 1; *Nonionella*, 1; and *Anomalinoides*, 2.

Six probable radiolarian species belonging to five genera and three families are included and six forms are described as *incertae sedis*.

The lower 312 feet of the Bearpaw Formation have been designated the *Eoeponidella strombodes* Zone and the upper 158

feet are referred to as the ?Cassidella sp. A "Zone".

The sediments in the thesis area are considered to have been deposited in shallow water, varying from inner to outer sublittoral marine.

Five episodes of increasing depth of water are interpreted from the increases in calcareous benthonic Foraminifera present in the Castor well core. The first episode is correlated with the basal Bearpaw Formation from the Bow City area and the final episode is correlated with the uppermost Bearpaw Formation from both the Bassano and Dorothy localities.

The lower boundary of the Bearpaw Formation in the thesis area is demonstrated to be somewhat diachronous. The correlation of the Castor well section with the Anomalinoides henbesti Zone of Caldwell and North (1964) indicates that the Bearpaw Formation of central southeastern Alberta is equivalent to the middle to upper half of the Manyberries Member of the southern Alberta Bearpaw Formation.

The fauna of the Bearpaw Formation in central southeastern Alberta is similar to that of the Sentinel Hill Member of the Schrader Bluff Formation of northern Alaska. Both contain many Lea Park Formation species, radiolarians and the Late Campanian foraminiferal species Eoeponidella strombodes Tappan. An open marine connection from western Canada to Alaska during some part of Bearpaw time is indicated.

ACKNOWLEDGEMENTS

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Frank Copeland and Ron Clouston of the Research Council of Alberta drafted the illustrations. Frank Dimitrov of the Department of Geology printed the plates and gave advice concerning photographic techniques. Mrs. Robin Wooller prepared thin sections of Foraminifera.

The Research Council of Alberta employed the author during the preparation of sample materials and field investigations, and made available core material and facilities which aided immeasurably during the preparation of the thesis.

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CHAPTER ONE - INTRODUCTION

Toward the end of Cretaceous time the great interior seaway that several times had linked the Gulf of Mexico to the Arctic Ocean and divided the continent of North America began to withdraw. Slowly the face of North America rose above the waters that had covered so much of it for so long. The Mesozoic Era was ending.

Regionally, such an ending did not mean catastrophic destruction so much as it meant change. With the progression of geologic time the distribution of the Bearpaw Sea against the land was gradually altered. The habitats of life were changed and, of necessity, the composition of that life was forced to change or to migrate with the consequent influx of new plants and animals.

Locally, however, the ending of the era meant, for the sea, a struggle for its existence. Great volumes of clastic material poured into the sea from a spine of land in the west where, one day, the Rocky Mountains would rise. Time after time the sea moved westward, covering the beaches. And time after time the sands smothered the margin of the sea, driving it eastward. Ultimately the land emerged.

The sea floor was gone and in its place were the swamps and plains of the new land. The sea dwellers all were gone and on the new land stood the great dinosaurs whose own demise would come so soon.

Very near where the town of Castor now stands, the northwestern shore of this last Bearpaw Sea oscillated back and forth across Alberta. What is now the rolling farmland south of the city of Edmonton was then a cool, shallow sea harboring millions of one-celled plants and animals. The rocks containing these tiny creatures and the record of their struggle to survive against the encroaching sands are all that remain to mark the presence of that last sea.

This thesis discusses the Foraminifera of the Bearpaw Formation in central southeastern Alberta and traces the movements of the nearby Cretaceous shoreline as they are reflected by the faunal record.

Area of study, sample localities and sampling procedures

The major portion of the information for the present study was derived from a complete core of the Bearpaw Formation taken from a well (RCA 13-34-37-13W4) drilled by the Research Council of Alberta near the town of Castor (figure 1). Supplementary samples were obtained from outcrop localities along the Red Deer River at East Coulee (MG 68-1) and Dorothy (MG 68-3 and 4), and along the Bow River near Bassano (JW 66-17, JW + MG 68-2 and 3) and Bow City (JW 66-18). Several miscellaneous shothole samples were obtained near the town of Big Stone.

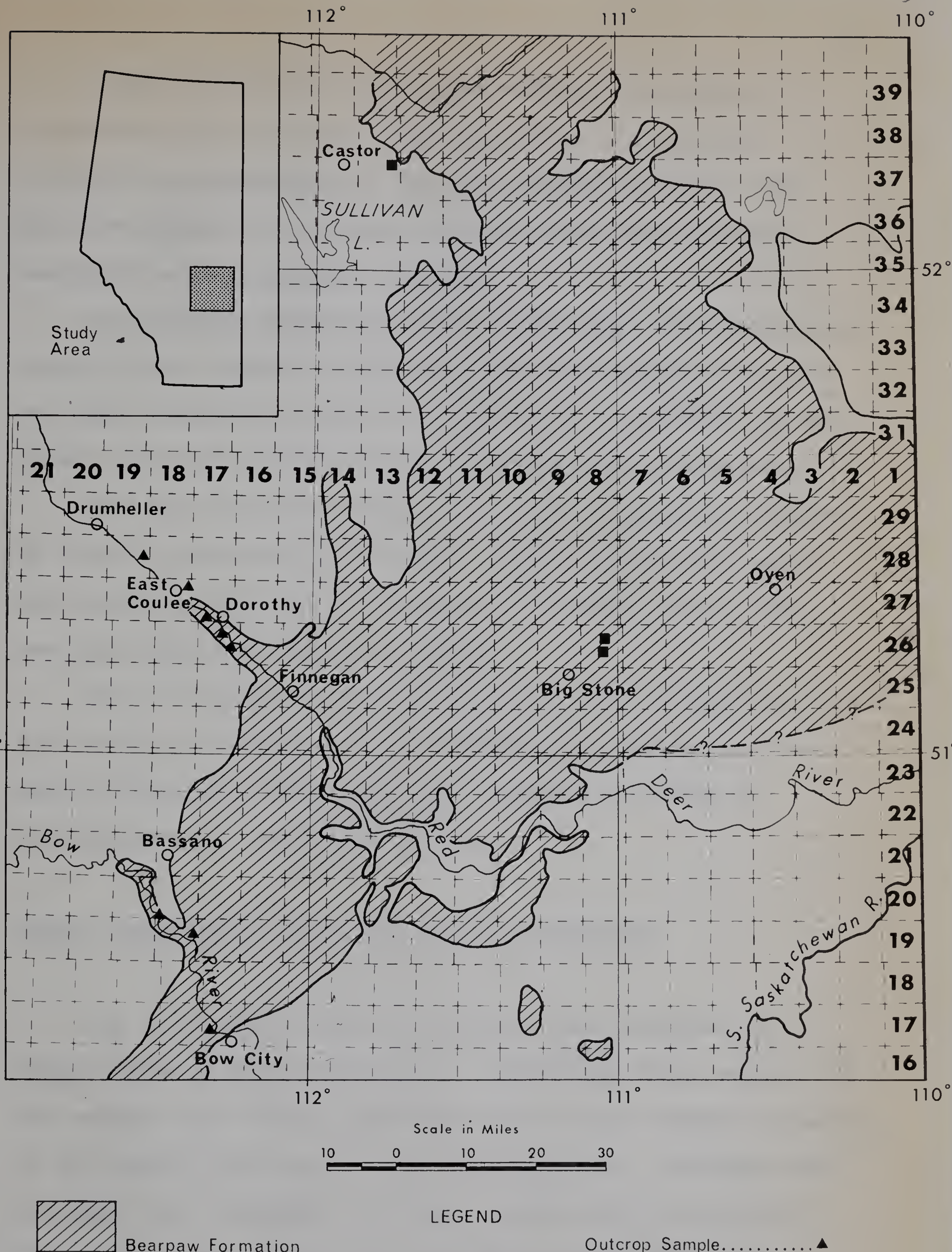


Figure 1. Location of Outcrop and Subsurface Samples, Bearpaw Formation, Central South-Eastern Alberta.

Complete descriptions of the samples and sample localities are included in the Appendix. An outcrop locality is designated by the collector's initials, the last two digits of the year of collection, and a number assigned to the specific location.

The outcrop areas are easily accessible from unimproved roads in dry weather. Although the rocks are well exposed at these localities, only the upper 90 to 225 feet, and the lower 110 feet of the Bearpaw Formation are represented.

The core from the Castor well was continuously sampled in four to seven foot intervals, except for the two major sand members, and some portions of the lower part of the section which are extremely sandy.

At the outcrop localities, samples were usually taken six to nine feet apart. This interval was reduced at formation contacts, where the shale appeared potentially fossiliferous or near marker beds.

Sample preparation and repository of materials

All the samples for this project were prepared by a simple water-washing technique. Relatively large samples of one hundred and fifty grams were used as the Bearpaw Formation in the thesis area is not very fossiliferous. Through many intervals the formation is silty, sandy and/or bentonitic. The samples were washed in a 200 mesh screen, then dried

and sieved into 40, 60, 80, +120, and -120 mesh fractions for picking.

All figured specimens, microfaunal assemblage slides, and the unprocessed portions of samples and core material discussed in this thesis are filed at the Research Council of Alberta. All figured specimens have been designated by the author's initials and a number from 1 to 87.

CHAPTER TWO - THE BEARPAW FORMATION

Previous work

The type section of the Bearpaw Formation was described by Stanton and Hatcher (1903) from the Bearpaw Mountains of Montana, where the formation is well developed around the north, east and south sides. Here the Bearpaw Shales overlie the nonmarine Judith River beds and were described as consisting of "dark clay shales with many calcareous concretions" most of which are fossiliferous. These authors noted the lithologic and paleontologic similarity of the Bearpaw Formation to the Pierre Shales, and recognized that the Bearpaw represents only a part of total Pierre deposition.

Stanton and Hatcher were able to trace the Bearpaw Formation and Judith River beds north of the International Boundary to an area in the Cypress Hills of southern Alberta mapped as Pierre Shales and Belly River Formation by Canadian geologists (Dawson, 1882-84). They thus confirmed Dawson's suggestion of Belly River and Judith River equivalence.

The findings of Stanton and Hatcher were originally published in a short note, but were later (1905) more fully developed and expanded in a United States Geologic Survey Bulletin.

The term "Bearpaw" was first used in the Canadian literature by Dowling (1917) when he published a macrofaunal list of the invertebrate species found in the formation. Dowling determined the thickness of the Bearpaw Formation on the

Stanton and Hatcher 1903	Sanderson 1931	Link and Childerhose 1931	Clark 1931	Russell and Landes 1940	Furnival 1946	Lines 1947 1963	Russell 1950	This thesis: Castor	This thesis: Dorothy
	St. Mary River	St. Mary River				Eastend	Eastend	Edmonton	Edmonton
Bearpaw	Fox Hills	Fox Hills	Fox Hills	Blood Reserve		Medicine Lodge			
	Bearpaw	U. Bearpaw: Ryegrass	Bearpaw: Upper Sand	Bearpaw	Thelma	Thelma			
					Belanger	Belanger	Middle Sand		
		Kipp	Middle Sand						
		Magrath			Oxarart	Oxarart			
		Lower Bearpaw	Lower Shale			Many-berries	Black Eagle		
						Paint-earth		Bearpaw: Upper Shale	Bearpaw
								First Castor Sst.	Dorothy Benton-ite
								Middle Shale	
						Young Creek		Second Castor Sst.	Dorothy Sand-stone
								Lower Shale	
Judith River		Pale Beds	Pale Beds			Oldman/ Belly River		Belly River	

Table I. Local terminology chart for Bearpaw Formation.

western slope of the Cypress Hills to be 622 feet.

Williams and Dyer (1930) established that the Bearpaw Formation was eroded from the higher portions of the Sweetgrass Arch, stating that the strata dip west to the west of the Arch and to the north and northeast on the eastern flank of the Arch. By measuring the distances between fossil zones, they arrived at a formation thickness of 525 feet north of the Cypress Hills.

In 1931, the Donaldson Bogart Dowling Memorial Symposium on the stratigraphy of the southern plains of Alberta was published. This symposium contains six papers dealing with specific sections of Upper Cretaceous strata including the Bearpaw and Fox Hills Formations, these being considered two separate formations at that time.

Sanderson (1931) proposed the use of the name "Fox Hills" for the marine sandstone above what was then considered to be the Bearpaw Formation and occurring immediately below the basal coal seam of the nonmarine St. Mary River Formation in southern Alberta. The Fox Hills Formation had originally been described by Meek and Hayden (1861) as a sandstone in South Dakota occurring above the Pierre Shales. It was also reported from Wyoming and Montana.

The Fox Hills Formation of southern Alberta was considered to be a well sorted beach sand, indicating slow deposition. Its thickness ranges from 31 to 327 feet south of the Bow River, and thickens to the west. North of the Bow River, the Fox Hills Formation could not be identified.

Link and Childerhose (1931) broadly divided the Bearpaw Formation into two parts in the Lethbridge area. The lower one-third of the formation consists of well-bedded, darker shales with almost no sand, and the upper two-thirds is light bluish, somewhat sandy shales containing three distinct sandstone members. In ascending order, these sandstones were named the Magrath, Kipp, and Ryegrass Sandstones. Formation thicknesses of 726 feet for the Bearpaw and 142 feet for the Fox Hills were measured in the Lethbridge area.

These authors considered deposition of the Bearpaw Shales to be slow as shown by the almost pure volcanic ash or bentonite beds which are frequently present in the section. The sandstone members were considered to show no wave action or undertow disturbance, and only the Ryegrass Sand was thought to represent the first indication of the gradual withdrawal of the Pierre Sea as the shales present above this sandstone become progressively arenaceous. The overlying Fox Hills Sandstone was considered a true beach deposit, representing the retreating shoreline and becoming successively younger southward.

Clark (1931), working in the area from Bassano to Lethbridge, showed that the Bearpaw Formation thins fairly uniformly northward. Thicknesses of 740 feet at Keho Lake in the south and 575 feet at the Bow River and Eyremore (Bow City) in the north were reported. Clark did not include thicknesses for the Fox Hills Sandstone, although he mapped this unit. Three units were established for the Bearpaw

Formation in this region. A lower shale was considered to represent deposition in quiet water far from shore. The middle sandy member was felt to represent partial regression of the sea with numerous offshore sands developed. Fluctuating conditions at the time of deposition were demonstrated by the numerous small sandstone lenses which are not traceable over any great distance. The upper sandy member consisted of sandy shales and interbedded sandstones becoming transitional with the overlying Fox Hills Sandstone.

Yarwood (1931) determined the thickness of the Bearpaw Formation southwest of Lethbridge to be 690 feet and the overlying Fox Hills Formation to be 135 feet thick.

Warren (1931) published a macrofaunal list of the invertebrate species from the Bearpaw Formation, and concluded that the Bearpaw marine fauna was long-ranging and representative of most of Late Cretaceous Montana time, and that the Fox Hills Formation contained the Bearpaw marine forms as well as more brackish water forms.

The first microfaunal data from the Bearpaw Formation were published by Wickenden (1932). His collections were from southern Alberta, and his work was of purely descriptive nature with no stratigraphic correlation attempted.

The term "Blood Reserve Formation" was proposed by Russell and Landes (1940) for the sandstone bed at the top of the Bearpaw Formation, replacing the term "Fox Hills".

Furnival (1946) introduced the names "Thelma", "Belanger", and "Oxarart" for the three successively older sandstone members of the upper Bearpaw Formation in southwest Saskatchewan. These sandstones were determined to be 30 to 50 feet thick at the Alberta-Saskatchewan boundary and to pinch out about 40 miles east of the boundary.

Lines (1947 in litt; 1963) made several important contributions to the understanding of Bearpaw stratigraphy in Alberta. In the Cypress Hills area he established two new members. The term "Manyberries" was used to differentiate the nonsandy lower portion of the Bearpaw Formation from the upper sandier portion. The term "Medicine Lodge" was applied to the dark grey shales above the Thelma Member and below the Eastend Formation. He traced the Thelma, Belanger, and Oxarart Members into this area.

The rapidity of the Bearpaw transgression was suggested by Lines who felt that the bentonites 60 to 100 feet above the Belly River Formation in the Lethbridge area might be the same as the bentonites in the Cypress Hills, making the top of the Oldman or Belly River Formations practically isochronous.

Lines stated that the Bearpaw Formation thins slightly in the Lethbridge region and considered the Blood Reserve Formation of the western region a possible equivalent of the Oxarart Sandstone of the eastern region.

Most important from the standpoint of this thesis is Lines' description of a composite section of the Bearpaw

Formation from the Castor area and his statement that the formation is more arenaceous in the north showing clearly how the Bearpaw Formation passes into nonmarine beds near the shoreline. A two member division of the Bearpaw was proposed for this section. The Paintearth and older Young Creek Members were considered equivalent to the lower half of the Manyberries Member in the south. The chert pebble bed separating these two members in the Castor area was suggested as the equivalent of the basal Edmonton conglomerate of the north-central Foothills area, assuming the diachroneity of the upper Bearpaw Formation boundary.

Russell (1950) combined the Belanger and Oxarart Sandstones and the intervening shale into a middle sandstone member in southeastern Alberta and introduced the name "Black Eagle" for the sandstone called Oxarart in this region by Furnival (1946). Russell stated that the Black Eagle Sandstone is 100 feet thick and occurs 40 feet below the Oxarart Sandstone.

Russell also recognized the diachroneity of the upper boundary of the Bearpaw Formation in southern Alberta and southwestern Saskatchewan. He stated that 200 feet of upper Bearpaw Shales in the southeast would be the time-equivalent of post-Bearpaw sediments in the western region.

Loranger and Gleddie (1953) attempted the first zonation of the Bearpaw Formation on the basis of Foraminifera recovered from corehole work in southwestern Saskatchewan.

The formation is 1030 feet thick here, and they have identified six zones, five of which are abundantly fossiliferous. They indicate that three of these zones are present in the Lethbridge area but in a more brackish environment. These authors reduced the Blood Reserve Formation to member status and substantiated the conclusion of Russell (1950) of the diachroneity of the upper Bearpaw Formation boundary moving from west to east in southern Alberta and Saskatchewan.

Caldwell and North (1964), in a short note, proposed three microfaunal zones for the Bearpaw Formation in southwestern Saskatchewan. The formation in the South Saskatchewan River valley is 900 feet thick and consists of five members, three of which are shales, separated by two sandstones. These authors suggest that their lower shale and sandstone members are equivalent to the lower half of the Manyberries Member and their middle shale to the upper half of the Manyberries Member. The upper sandstone is considered equivalent to at least part of the Oxarart, and the upper shale to the Belanger, Thelma, and Medicine Lodge Members. They state that the ammonoid and pelecypod distributions support this conclusion.

North and Caldwell (in press) have recently completed a microfaunal study of the Bearpaw Formation in Saskatchewan for the Saskatchewan Research Council.

Fellow graduate students at the University of Alberta are presently engaged in a number of projects concerning the micropaleontology of the Bearpaw Formation in Alberta.

R. Anan-Yorke is preparing an M. Sc. thesis on the Foraminifera of the Lethbridge area, and R. Harland is engaged in a study of the dinoflagellates as a doctoral thesis.

Description of the Bearpaw Formation

The marine shales and sandstones of the Bearpaw Formation represent the last northern transgression of the Late Cretaceous Pierre Sea (Link and Childerhose, 1931). Marine fossils present in the formation date this transgression as Late Campanian (Jeletzky, 1967). The Bearpaw Formation is encompassed by most or all of the *Baculites compressus* Zone of Jeletzky (1967), in the interior plains and Foothills region of western North America.

A potassium-argon age determination by Folinsbee *et al.*, (1960, 1961) on a bentonite 65 feet above the base of the Bearpaw Formation gave a date of 75 $\pm$ 4 million years.

The Bearpaw Sea is known to have extended as far north as the Edmonton area (Feniak, 1944 *in* Williams and Burk, 1964), west into British Columbia at the United States border (Lines, 1963), and into the Foothills region in the southern part of the province (Williams and Burk, 1964). Eastward, the Bearpaw Formation is represented by the upper part of the Riding Mountain Formation in Manitoba. The northern limit of the sea in Saskatchewan and Manitoba is unknown and the present distribution of the formation is controlled by post-Bearpaw erosion.

Several occurrences of supposedly Late Campanian shales in the Northwest Territories in the area between Great Bear Lake and the Richardson Mountains suggest an extension of the Bearpaw Sea through northern Saskatchewan (Martin, 1961).

In Alberta, the distribution of outcrops of the Bearpaw Formation may be divided into three main belts (Russell, 1950). The western belt is within the Foothills of the Rocky Mountains and, being in the western arm of the Alberta syncline, the strata dip strongly eastward. In this region the formation thickness is difficult to determine due to faulting and folding. The formation is probably no longer present north of the Bow River in the west (Williams and Burk, 1964).

The central outcrop belt extends from the Foothills to the Sweetgrass Arch and from the 49th parallel to about 50 miles northwest of Edmonton (Feniak, 1944 <u>in</u> Williams and Burk, 1964). The thickness of the formation is about 810 feet in the south (Lines, 1963), and gradually thins to the north and west. East of Calgary, the Bearpaw Formation is 350 feet thick and in the Pembina field west of Edmonton, it is 100 feet thick or less according to well log data (Williams and Burk, 1964).

The Bearpaw Formation is generally absent from the structurally high Sweetgrass Arch where older strata are exposed (Williams and Dyer, 1930; Russell, 1950).

The eastern outcrop belt of the Bearpaw Formation is in

the Cypress Hills where the formation is about 1030 feet thick (Loranger and Gleddie, 1953). East of the Arch, the Bearpaw strata dip very gently westward (Russell, 1950).

The lower contact of the Bearpaw Formation and the underlying nonmarine Oldman or Belly River Formations is sharp and apparently conformable, representing a rapid transgression of the sea (Lines, 1963). The contact is placed at the top of the uppermost coal-bearing and carbonaceous shale beds of the Belly River Formation (Ower, 1960 in Williams and Burk, 1964).

The upper contact of the Bearpaw Formation with the nonmarine Edmonton, St. Mary River, or Eastend Formations is gradational and diachronous. These formations replace the Bearpaw Shales vertically in the section as well as laterally to the north and west (Williams and Burk, 1964).

The Bearpaw Formation marine shales are generally dark grey, weathering to brownish-grey. The silty shales are brown-grey. Fresh shales may be blocky or laminar. Selenite crystals and iron oxide staining are frequently present on outcrop surfaces.

The sandstone beds of the Bearpaw Formation are medium to fine grained and often glauconitic. Numerous sandy lenses are present locally and are not traceable for any great distance.

Local marker beds may be provided by bands of clay ironstone concretions which are often fossiliferous. Bentonite beds are common in the Bearpaw Formation, ranging from a fraction of an inch thick to as much as 30 feet thick, and

are also useful local markers.

Regional correlation

A partial regional correlation chart for Late Cretaceous strata in western Canada, Alaska, the western interior, and Gulf Coastal regions of the United States is shown in figure 2.

The Pierre Group of the Black Hills and eastern Montana is divided into three formations and represents a complete record of deposition of the last Cretaceous sea. Pierre Shales are present in Nebraska and Kansas but the boundaries are marked by unconformities.

The upper unnamed member of the Pierre Shale and the lower portion of the Montana Group are, in part, correlative with the Bearpaw Formation, but the Pierre represents a more complete and long-lasting record of transgression.

On the Gulf Coast, the Navarro and Taylor Groups of the Gulf Series are equivalent to most of the Pierre Group. The Bearpaw Formation is correlative with upper Taylor and Navarro strata.

The Schrader Bluff Formation of northern Alaska is divided into three members. From oldest to youngest these are the Rogers Creek, the Barrow Trail, and the Sentinel Hill Members (Payne *et al.*, 1951). The uppermost Barrow Trail and the Sentinel Hill Members are correlative with the Bearpaw Formation.

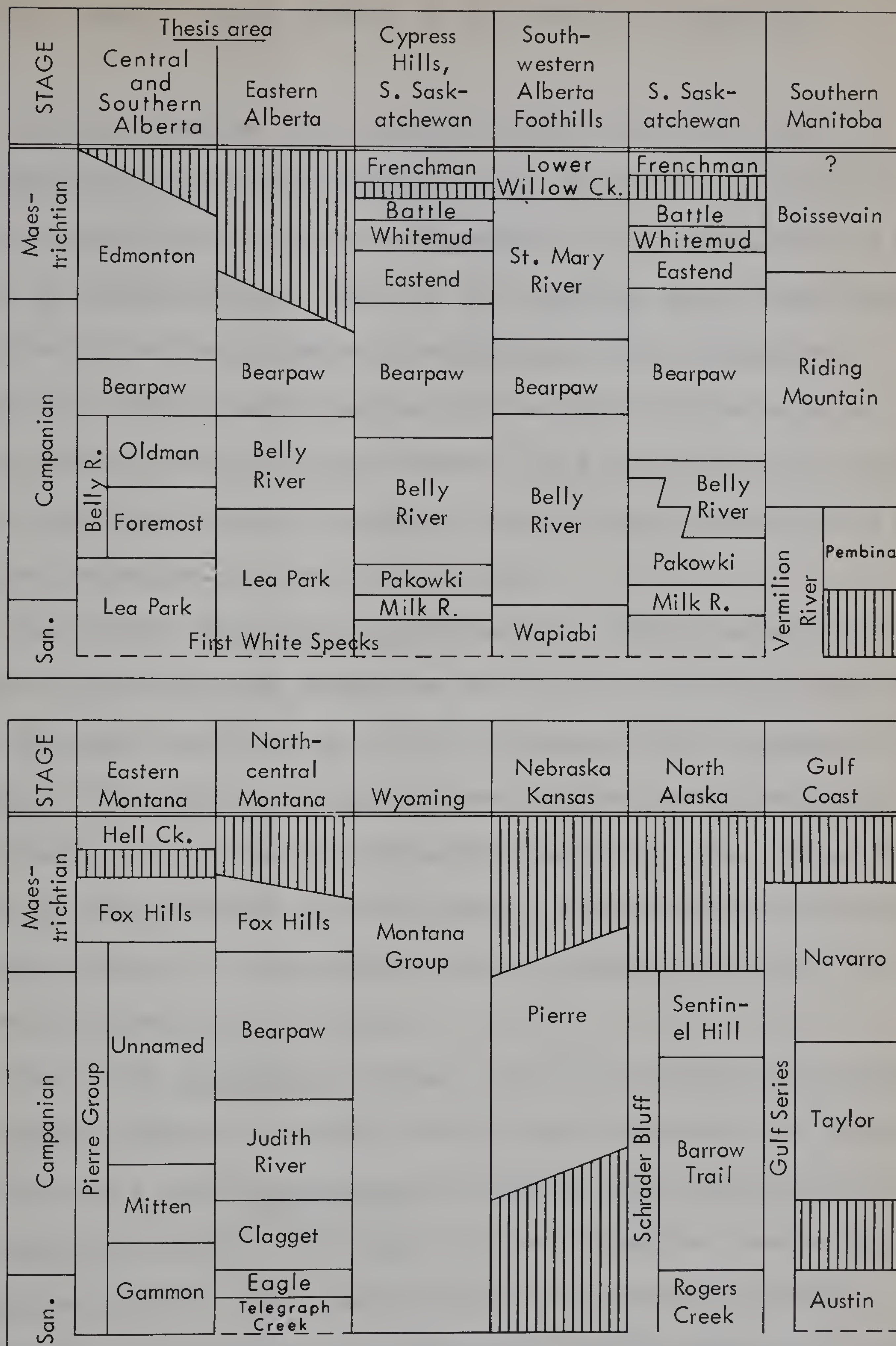


Figure 2. Correlation chart of Late Cretaceous strata above first white speckled shale in western Canada, Alaska, the western interior and Gulf Coastal regions of the United States. Stratigraphy after Cobban and Reeside (1952), Tappan (1960, 1962) and Williams (1964).

CHAPTER THREE - FORAMINIFERA OF THE BEARPAW FORMATION

In this chapter the foraminiferal content of each of the available sections of the Bearpaw Formation is discussed in an attempt to arrive at a zonation of the formation on the basis of Foraminifera. Most of the species which have been described from the Bearpaw or equivalent Late Campanian strata are rather long-ranging in the Upper Cretaceous of North America, and for this reason, it is difficult to establish a satisfactory or workable foraminiferal zonation of the Bearpaw Formation in the thesis area.

One genus, *Eoeponidella* Wickenden, 1949 is apparently unique to the Bearpaw Formation and to the partially correlative Sentinel Hill Member of the Schrader Bluff Formation of Alaska. The genus is very abundant in the lower two-thirds (312 feet) of the Bearpaw Formation core from the Castor well. Based on the presence of this genus a division into two foraminiferal "zones" is suggested for the Bearpaw Formation in central southeastern Alberta.

The genus *Cassidella* Hofker, 1951 is reported by Loeblich and Tappan (1964) as ranging from Upper Cretaceous to Recent. In the thesis area *Cassidella* is tentatively identified from the upper one-third (158 feet) of the formation, where *Eoeponidella* is absent. This pattern of occurrence is probably related to the progressive shallowing and decreasingly brackish nature of the sea.

Preservation of the Foraminifera is moderately good in most of the samples of the Bearpaw Formation used in this study.

Many of the specimens recovered from the Bow City outcrop samples are extremely well preserved.

Foraminifera from the Castor Well (RCA 13-34-37-13W4)

The entire Bearpaw Formation is represented by the core from the Castor well. The formation is 470 feet thick at this location and lithologically consists of three shale members separated by two sandstone members designated the "First Castor Sandstone" and the "Second Castor Sandstone". Certain species of Foraminifera are long-ranging in the Castor well and, therefore, not useful for the purposes of zoning the Bearpaw Formation from this well. The accompanying range chart (figure 3) illustrates the ranges of the foraminiferal species present in the Bearpaw Formation recovered from the Castor well. Of the 31 species present, 13 arenaceous and five calcareous species occur in all three shales. The 18 species found throughout the Bearpaw Formation are:

Anomalinoides talaria (Nauss)
Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. cf. *H. collyra* Nauss
H. sp. A
H. sp. C
Neobulimina canadensis Cushman and Wickenden
Praebulimina carseyae (Plummer)
P. sp. cf. *P. venusae* (Nauss)
Saccammina lathrami Tappan
S. sp. A
S. sp. B
S. sp. C
S. sp. D
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

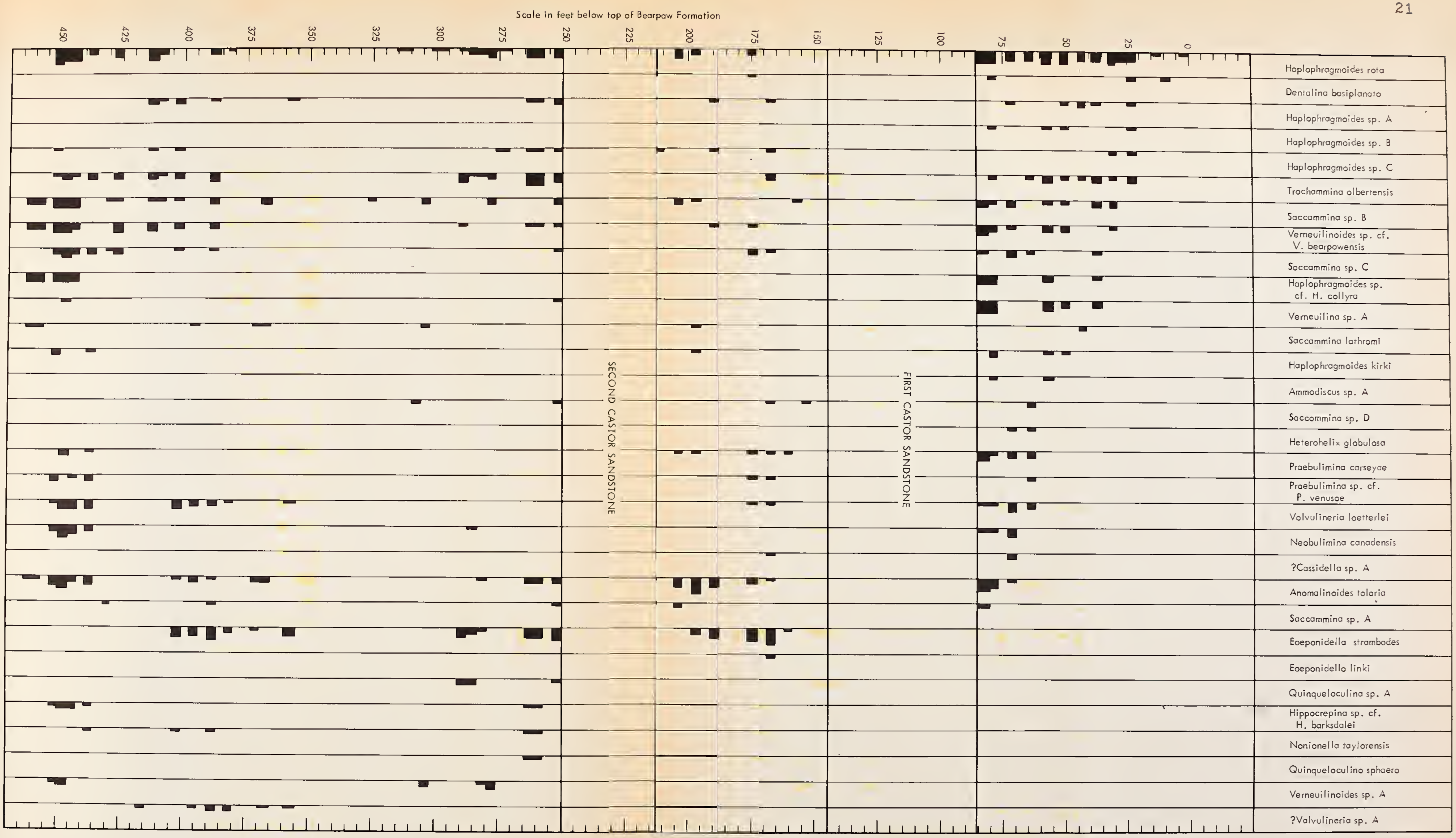


FIGURE 3: Range Chart of Foraminiferal Species from Bearpaw Formation near Castor, Alberta (RCA 13-37-34-13W.4)

1 - 2 specimens
3 - 10 "
11 - 50 "
51 - 100 "
>100 "

Six species are restricted to the lowermost shale member at Castor. These are:

Hippocrepina sp. cf. _H._ _barksdalei_ (Tappan)
Nonionella _taylorensis_ Hofker
Quinqueloculina _sphaera_ Nauss
_Q._ sp. A
?_Valvulineria_ sp. A
Verneuilinoides sp. A

One species, _Eoeponidella_ _linki_ Wickenden, occurs in the middle shale member and one species, _Eoeponidella_ _strombodes_ Tappan, is restricted to the lower and middle shale members.

Three species are restricted to the uppermost shale member at Castor. These are:

Ammodiscus sp. A
Haplophragmoides sp. B
Heterohelix _globulosa_ (Ehrenberg)

Two species are restricted to the middle and upper shale members. These are:

?_Cassidella_ sp. A
Dentalina _basiplanata_ Cushman

Foraminifera from the Bow City locality (JW 66-18)

The Bow City section comprises only the lower 110 feet of the Bearpaw Formation and is a completely shaly section with a few very thin bentonite seams present. The ranges of the 24 foraminiferal species present in this section are shown in figure 4.

Sixteen of the species present at Bow City are found also throughout the entire Castor section. These are:

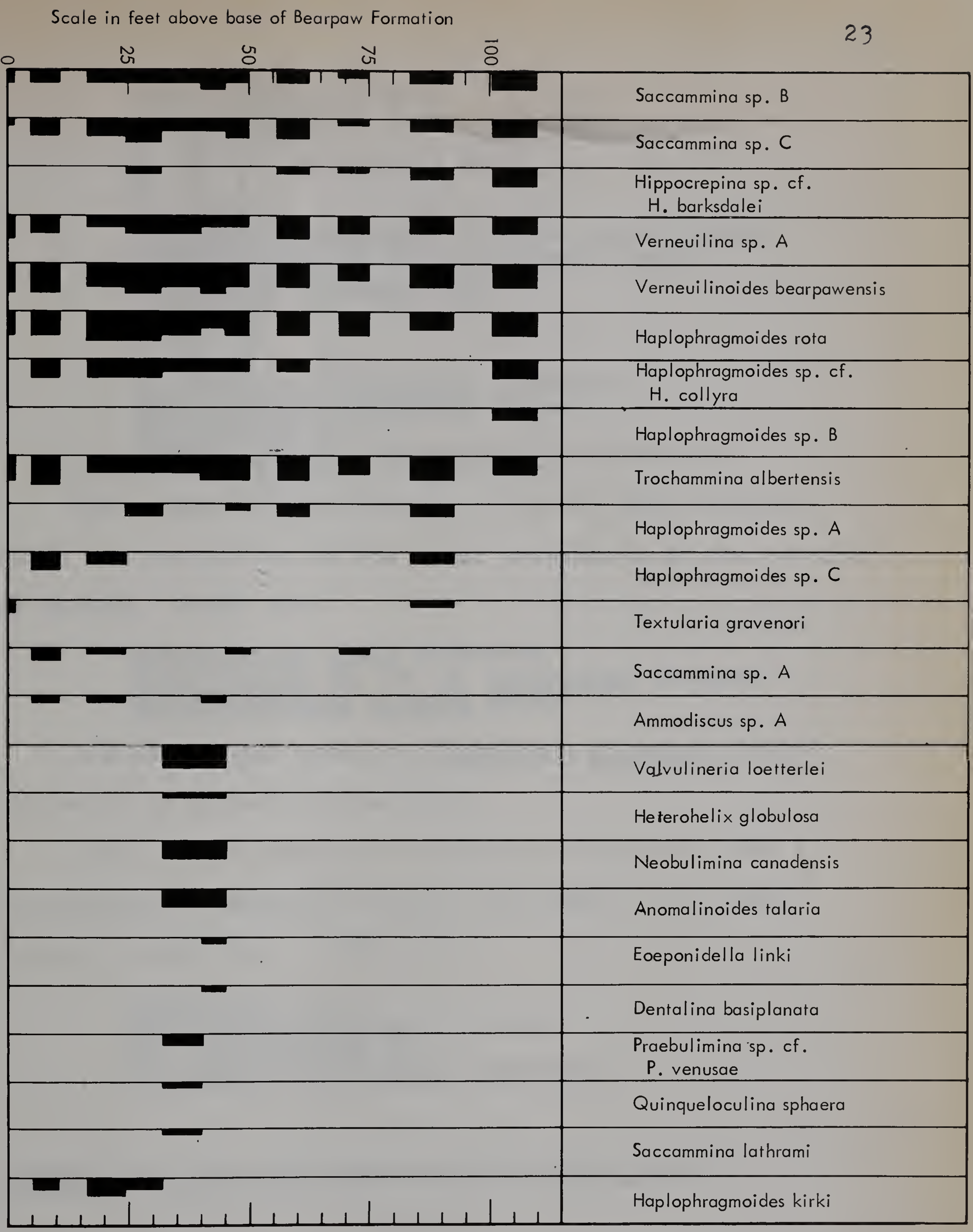


FIGURE 4: Range Chart of Foraminiferal Species from Bearpaw Formation near Bow City, Alberta (JW66-18).

1 - 2 specimens
3 - 10 "
11 - 50 "
51 - 100 "
>100 "

Anomalinoides talaria (Nauss)
Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. cf. H. collyra Nauss
H. sp. A
H. sp. C
Neobulimina canadensis Cushman and Wickenden
Praebulimina sp. cf. P. venusae (Nauss)
Saccammina lathrami Tappan
S. sp. A
S. sp. B
S. sp. C
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides bearpawensis (Wickenden)

Three species are present in the Bow City section which are restricted to the lower two-thirds of the section at Castor. These are:

Eoeponidella linki Wickenden
Hippocrepina sp. cf. H. barksdalei (Tappan)
Quinqueloculina sphaera Nauss

One additional species, Textularia gravenori Stelck and Wall, is present at Bow City.

Four species which are present in the upper zone of the Bearpaw Formation at Castor are found in the basal Bearpaw at Bow City. These are:

Ammodiscus sp. A
Dentalina basiplanata Cushman
Haplophragmoides sp. B
Heterohelix globulosa (Ehrenberg)

Foraminifera from the Bassano locality (JW 66-17)

The Bearpaw Formation exposed at Bassano consists of the uppermost 92 feet of the formation. Figure 5 illustrates the ranges of the 16 species of Foraminifera present in this section. Nine of these species are long-ranging in

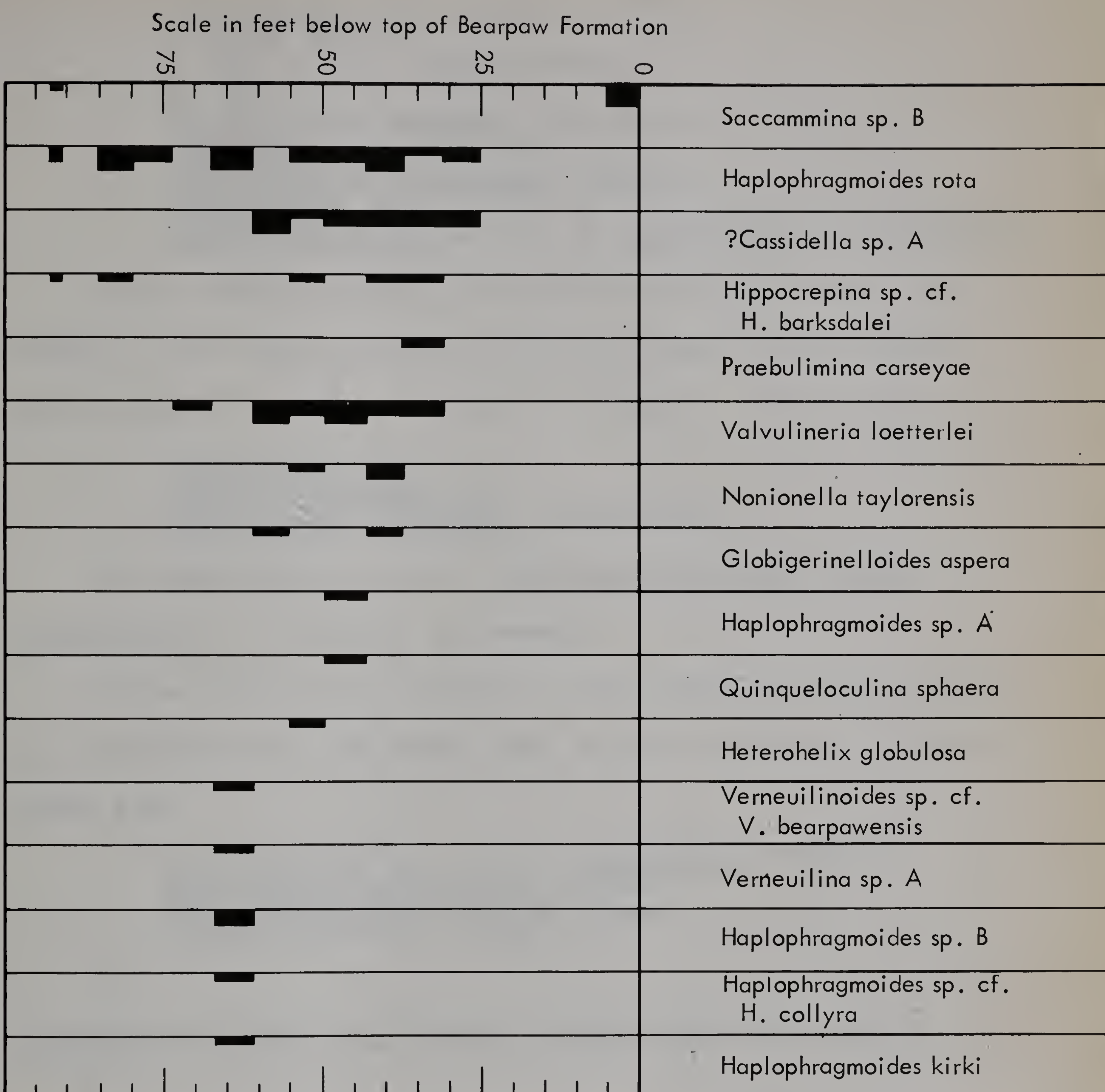


FIGURE 5: Range Chart of Foraminiferal Species from Bearpaw Formation near Bassano, Alberta (JW66-17).

1 - 2 specimens
3 - 10 "
11 - 50 "
51 - 100 "

the Castor section. These are:

Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. cf. *H. collyra* Nauss
H. sp. A
Praebulimina carseyae (Plummer)
Saccammina sp. B
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

Three species which are restricted to the upper one-third of the Castor section are also found in the uppermost Bearpaw Formation exposed at Bassano. These are:

?*Cassidella* sp. A
Haplophragmoides sp. B
Heterohelix globulosa (Ehrenberg)

One additional species, *Globigerinelloides aspera* (Ehrenberg), is present at Bassano.

Three species are present in the Bassano section which are restricted to the lower part of the formation at Castor. These are:

Hippocrepina sp. cf. *H. barksdalei* (Tappan)
Nonionella taylorensis Hofker
Quinqueloculina sphaera Nauss

Foraminifera from the Dorothy locality (MG 68-3 and 4)

The section of the Bearpaw Formation exposed at Dorothy comprises approximately the upper 225 feet of the formation. Lithologically, it includes a major bentonite seam, the "Dorothy Bentonite", one major sandstone, the "Dorothy Sandstone", as well as numerous smaller sandstone beds. The ranges of the 16 foraminiferal species present in the Dorothy

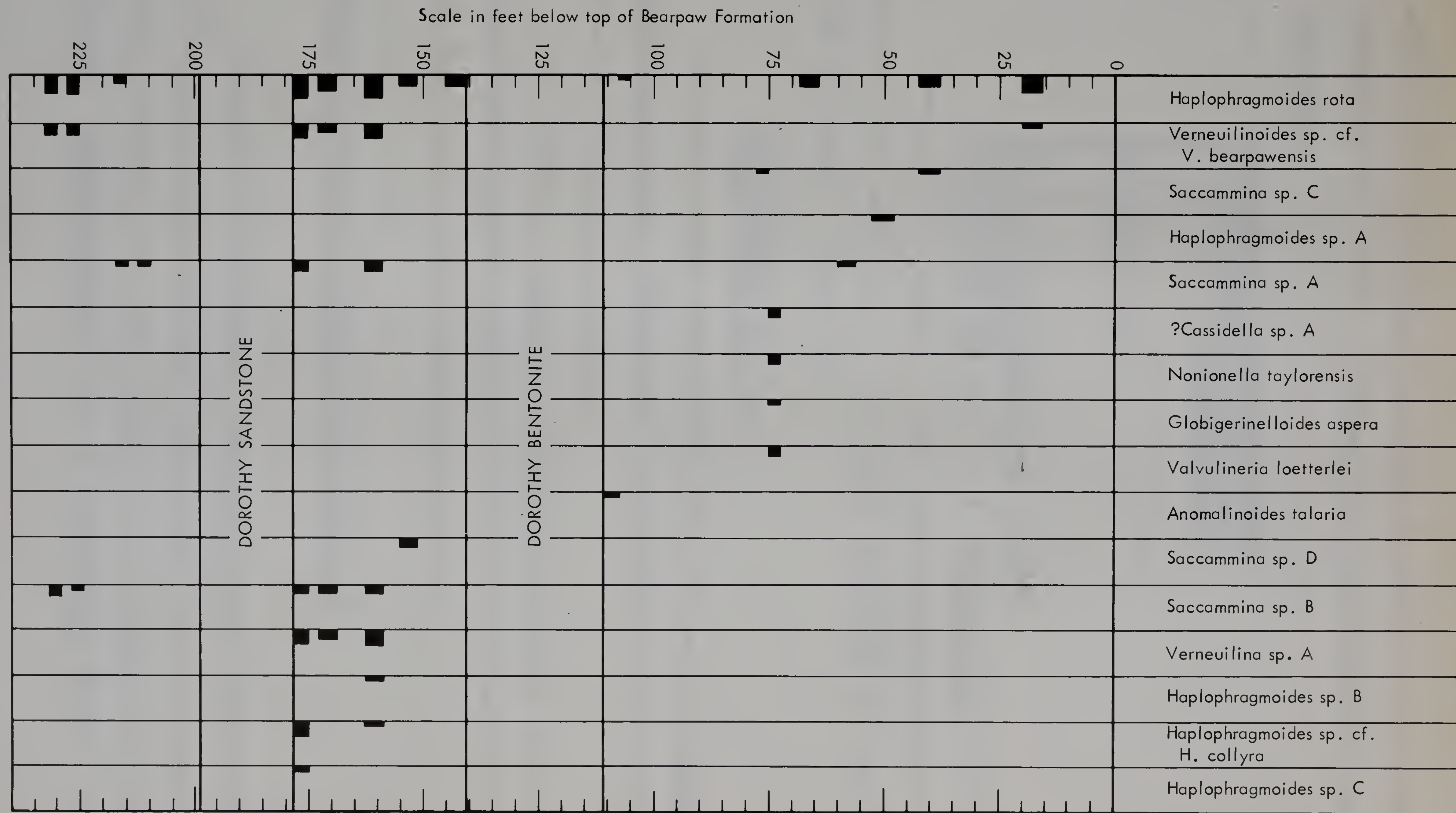


FIGURE 6: Range Chart of Foraminiferal Species from Bearpaw Formation near Dorothy, Alberta (MG68 - 3 and 4)

1 - 2 specimens
3 - 10 "
11 - 50 "
51 - 100 "

section are illustrated in figure 6. Twelve of the species present in the Dorothy section are long-ranging at Castor. These are:

Anomalinoides talaria (Nauss)
Haplophragmoides rota Nauss
H. sp. cf. *H. collyra* Nauss
H. sp. A
H. sp. C
Saccammina sp. A
S. sp. B
S. sp. C
S. sp. D
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

Two species present in the upper Bearpaw Formation at Dorothy are restricted to the upper one-third of the formation at Castor. These are:

?*Cassidella* sp. A
Haplophragmoides sp. A

One additional species not found at Castor, *Globigerinelloides aspera* (Ehrenberg), is present at Dorothy and also at the Bassano locality.

One species, *Nonionella taylorensis* Hofker, is present in the upper Bearpaw Formation at Dorothy and restricted to the lower part of the formation at Castor.

Proposed zonation of the Bearpaw Formation

Several of the species restricted to the basal 312 feet of the Bearpaw Formation at Castor range into the upper part of the formation at other localities in central southeastern Alberta. *Hippocrepina* sp. cf. *H. barksdalei* (Tappan) and

Quinqueloculina sphaera Nauss are present in the upper 100 feet of the Bearpaw Formation at the Bassano locality. *Nonionella taylorensis* Hofker is present in the upper Bearpaw Formation at both the Bassano and Dorothy localities.

On the basis of the present collections the only species that are restricted to the lower two-thirds of the Bearpaw Formation in the thesis area are:

Eoeponidella linki Wickenden
E. strombodes Tappan
Quinqueloculina sp. A
?*Valvulineria* sp. A
Verneuilinoides sp. A

With the single exception of ?*Cassidella* sp. A, all of the species restricted to the upper Bearpaw Formation at Castor are found in the basal Bearpaw Formation at the Bow City locality. However, ?*Cassidella* sp. A was identified from both the upper Bearpaw sections at Bassano and Dorothy, and it has not been found with species of *Eoeponidella*.

Considering these species ranges, two foraminiferal assemblage "zones" may be suggested for the Bearpaw Formation at Castor. A lower zone, the basal 312 feet of the formation, is named the *Eoeponidella strombodes* Zone, as this is the most distinctive and a very abundant species in the interval.

The upper one-third (158 feet) of the Bearpaw Formation from the Castor well may only informally be considered as an assemblage zone with ?*Cassidella* sp. A the only form unique to this portion of the section.

Comparison of Bearpaw Foraminifera with Alaskan, Gulf Coast and Alberta-Saskatchewan Foraminifera

The species of Foraminifera described from the Bearpaw Formation of central southeastern Alberta include a number of species which have been reported also from the Schrader Bluff Formation of northern Alaska (Tappan, 1960, 1962). The species of this Trochammina ribstonensis-Neobulimina canadensis Zone which are also found in the Bearpaw Formation are:

Anomalinoides talaria (Nauss)
A. pinguis (Jennings)
Dentalina basiplanata Cushman
Eoeponidella linki Wickenden
E. strombodes Tappan
Heterohelix globulosa (Ehrenberg)
Hippocrepina barksdalei (Tappan)
Neobulimina canadensis Cushman and Wickenden
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
P. venusae (Nauss)
Quinqueloculina sphaera Nauss
Saccammina lathrami Tappan
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)

Tappan (1960) suggested a subzone for the upper member of the Schrader Bluff Formation, the Sentinel Hill Member, and the species she states which are restricted to this member that are also present in the Bearpaw Formation are:

Nonionella taylorensis Hofker
Eoeponidella linki Wickenden
E. strombodes Tappan
Trochammina albertensis Wickenden

Bergquist (1966) has also listed species of Foraminifera from the Schrader Bluff Formation of northern Alaska. He prefers the name Neobulimina canadensis Zone to Tappan's

dual name as *Trochammina ribstonensis* is equally abundant in the older Seabee Formation according to his data. Bergquist also stated that *Anomalinoides talaria* (Nauss) or *Gavelinella ammonoides* (Reuss) are of equal or greater abundance than *Neobulimina canadensis* Cushman and Wickenden and so either could have been used to name this zone. His list, which differs slightly from that of Tappan, contains the following species which are also present in the Bearpaw Formation of central southeastern Alberta:

Anomalinoides talaria (Nauss)
A. pinguis (Jennings)
Dentalina basiplanata Cushman
Eoeponidella linki Wickenden
E. strombodes Tappan
Haplophragmoides rota Nauss
Neobulimina canadensis Cushman and Wickenden
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
P. venusae (Nauss)
Quinqueloculina sphaera Nauss
Saccammina lathrami Tappan

Bergquist has also listed two radiolarian species which are also probably present in the Bearpaw Formation. These are:

Dictyomitra multicostata Zittel
Spongodiscus sp.

Bergquist also listed foraminiferal species from each of the three members of the Schrader Bluff Formation and stated that several species which Tappan said were restricted to the Sentinel Hill Member are found in all three members of the formation.

Foraminiferal species from 40 outcrop samples of the Rogers Creek Member which are also found in the Bearpaw

Formation are:

Anomalinoides talaria (Nauss)
Haplophragmoides rota Nauss
Quinqueloculina sphaera Nauss
Saccammina lathrami Tappan

Foraminiferal species from 101 outcrop samples of the Barrow Trail Member which are also found in the Bearpaw Formation are:

Anomalinoides talaria (Nauss)
Haplophragmoides rota Nauss
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
P. venusae (Nauss)
Quinqueloculina sphaera Nauss
Saccammina lathrami Tappan

The radiolarian species, Dictyomitra multicostata Zittel, is also present in both the Barrow Trail Member and the Bearpaw Formation.

Foraminiferal species from 69 outcrop samples of the Sentinel Hill Member which are also found in the Bearpaw Formation are:

Anomalinoides pinguis (Jennings)
Eoeponidella strombodes Tappan
Haplophragmoides rota Nauss
Neobulimina canadensis Cushman and Wickenden
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
Quinqueloculina sphaera Nauss
Saccammina lathrami Tappan

Bergquist also stated that the lower part of the Sentinel Hill Member contains an abundant and conspicuous radiolarian fauna. Dictyomitra multicostata Zittel and Spongodiscus sp. are common to both the Sentinel Hill Member and the Bearpaw Formation.

Bergquist (1956) defined a subzone of the Neobulimina

canadensis Zone for the Sentinel Hill Member of the Schrader Bluff Formation. He designated this the Eoeponidella strombodes Subzone as this species is apparently confined to beds of Late Senonian age.

Comparison of the Bearpaw Formation species with Gulf Coast forms of Navarro and Taylor ages does not show as great a faunal similarity. The forms in common are:

Dentalina basiplanata Cushman
Heterohelix globulosa (Ehrenberg)
Neobulimina canadensis Cushman and Wickenden
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
Verneuilinoides bearpawensis (Wickenden)

Many of the 23 species described in this thesis from the Bearpaw Formation as hypotypes (or sp. cf. known taxa) have been reported from strata of Lea Park age in east-central Alberta (Nauss, 1947) and west-central Saskatchewan (Caldwell and North, 1964). The species in common are:

Anomalinoides talaria (Nauss)
Bathysiphon vitta Nauss
Dentalina basiplanata Cushman
Globigerina aspera (Ehrenberg)
Haplophragmoides kirki Wickenden
H. rota Nauss
H. collyra Nauss
Heterohelix globulosa (Ehrenberg)
Neobulimina canadensis Cushman and Wickenden
Praebulimina venusae (Nauss)
Quinqueloculina sphaera Nauss
Saccammina cf. lathrami Tappan
Verneuilinoides cf. bearpawensis (Wickenden)

Wall (1967) reported several species from the Nomad Member of the Wapiabi Formation of the Foothills of Alberta which he considered to be correlative with the microfaunal elements of the upper Lea Park and marine tongues of the

Belly River Formation. The species that are common to the Bearpaw Formation and the Nomad Member are:

<u>Anomalinoides</u> <u>talaria</u> (Nauss)
<u>Eoeponidella</u> sp. cf. <u>E.</u> <u>linki</u> Wickenden
<u>Praebulimina</u> <u>venusae</u> (Nauss)
<u>Verneuilinoides</u> <u>bearpawensis</u> (Wickenden)

From the foregoing faunal lists, it becomes apparent that many of the foraminifers of the Bearpaw Formation in central southeastern Alberta are the direct descendants of the Foraminifera of the Lea Park Formation from east-central Alberta and west-central Saskatchewan. Several of the species reported from the Lea Park and Bearpaw Formations are found in the marine tongues of the intervening Belly River Formation.

Caldwell and North (1964) suggest that the Lea Park Formation species are probably descendants of migrants from the northern and southern seas that invaded North America during Cretaceous times as the Lea Park fauna shows an affinity to the Gulf Coastal fauna almost as great as it does to the Schrader Bluff fauna.

The fauna recovered from the Bearpaw Formation in the thesis area suggests that with the deposition, in Alberta, of the nonmarine Belly River Formation from the west, the Lea Park Sea withdrew eastward. The marine tongues of the Belly River Formation were deposited by minor westward transgressions of the sea. In Saskatchewan and Manitoba the Lea Park and Bearpaw Formations are not separated, but are designated by the term Marine Shale Series (Caldwell and North, 1964). The fauna of the Lea Park Formation of the Alberta-

Saskatchewan region apparently migrated eastward with the regressing sea and remained viable, with few exceptions, until the new transgressive episode of the Bearpaw Sea, which reintroduced the fauna into the central southeastern region of Alberta. Some of the faunal elements of the Bearpaw Formation in the thesis area suggest a connection with northern Alaska during Late Cretaceous time.

CHAPTER FOUR - PALEOECOLOGY OF THE BEARPAW FORMATION

Although arenaceous Foraminifera dominate the assemblages found in the sections of the Bearpaw Formation studied in this thesis, there are several intervals containing certain calcareous species in moderate abundance. These increases in the numbers of calcareous species and numbers of individuals are interpreted as a reflection of a deepening of the sea with development of a more open marine shelf environment. The alternate shallowing of the sea is considered a reflection of increased tectonic activity and uplift in the Cordilleran region, with rejuvenated streams carrying massive loads of clastic sediments which were deposited near the shoreline of the sea. It is concluded that the depositional environments varied from littoral to neritic, or sublittoral, with the inner sublittoral zone (water depth less than 150 feet) being the most important.

Eicher (1967) has stated that an abrupt transition from calcareous benthonic to arenaceous foraminiferal species domination occurs at the boundary between the shelf and "marsh-lagoon" depositional environments. In the shelf region, although calcareous benthos are more important, a few arenaceous forms are present. The reverse is found in the "marsh-lagoon" environment. This idea is an extension of the finding in modern environments of planktonic foraminiferal species domination of the continental slope region, and calcareous benthonic domination of the continental shelf region (Grimsdale and Morkhoven, 1955).

Based on the ratio of arenaceous to calcareous benthonic foraminifers, five separate cycles of deposition are detected from the fauna present in the Castor section. The basal Bearpaw Formation from Bow City shows a similar deepening which may be correlated with the basal Castor deepening. Both the Bassano and Dorothy sections show a final deepening of the sea in the upper part of the formation which may be correlated with the last deepening noted from the Castor section. Figure 7 illustrates the proposed correlation of these Bearpaw Formation sections.

Castor Well (RCA 13-34-37-13W4)

Throughout the core of the Bearpaw Formation recovered from the Castor well there are numerous species of megaspores with many individuals of the species present. Bentonitic material is disseminated through most of the core with a number of small seams present as well.

Basal depositional unit (34 feet thick):

The first seven feet of this unit contain abundant plant fragments and pelecypod shell fragments, and suggest deposition in a very shallow, brackish environment (deltaic to littoral).

The next ten feet of the unit show the introduction of four arenaceous and one calcareous species of benthonic Foraminifera, suggesting very gradual deepening of the water to the inner sublittoral zone. Worm burrows and bone frag-

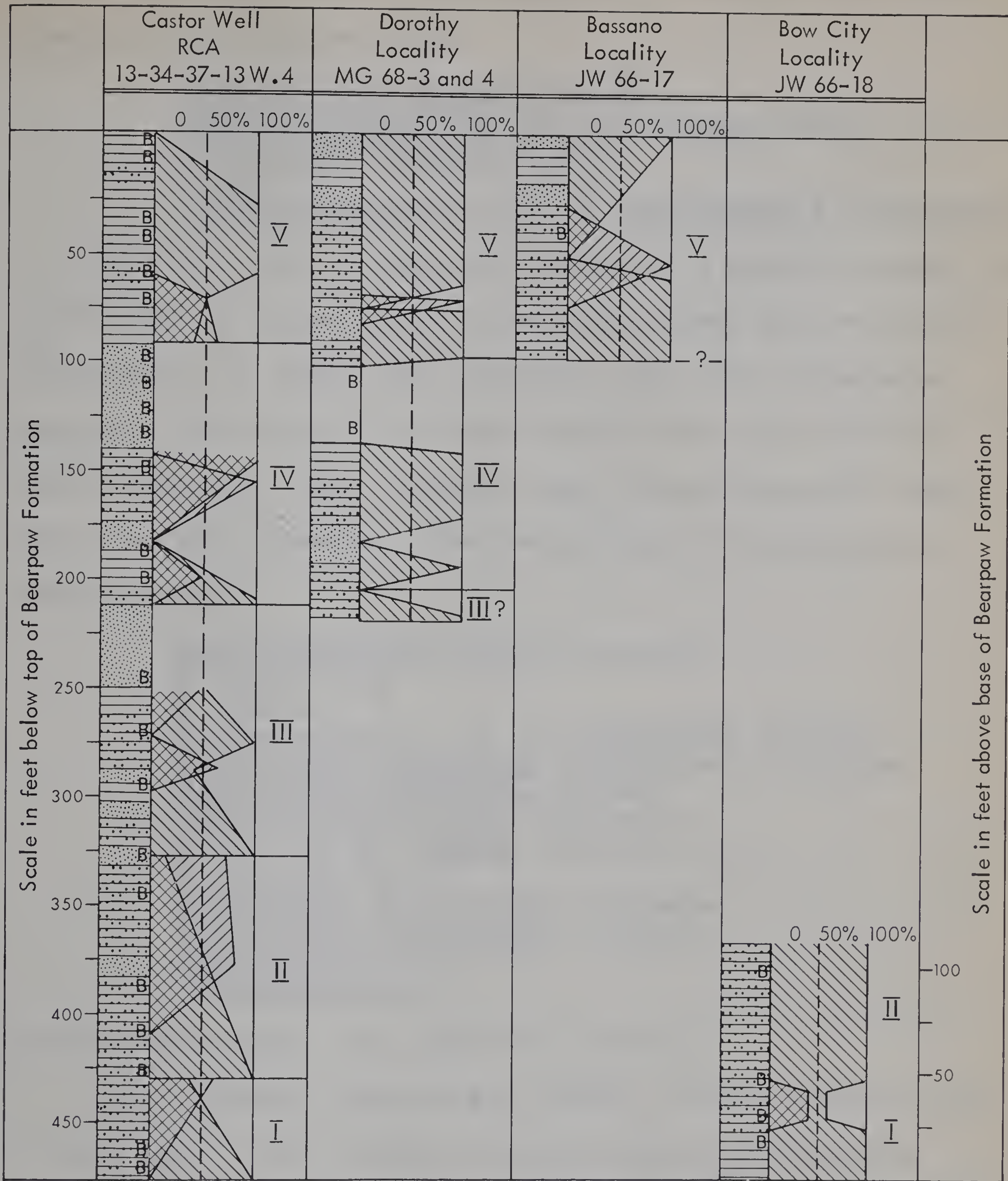
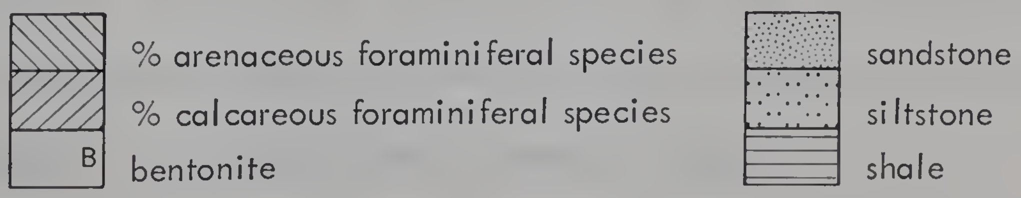


Figure 7. Correlation chart for Bearpaw Formation, central southeastern Alberta.



ments are also present. The species of Foraminifera introduced in this interval are:

Anomalinoides talaria (Nauss)
Haplophragmoides sp. cf. H. collyra Nauss
Saccammina lathrami Tappan
S. sp. B
Verneuilinoides sp. cf. V. bearpawensis (Wickenden)

The last half of this unit suggests a marked increase in water depth to perhaps the outer sublittoral zone with the introduction of eight new arenaceous and five calcareous species. Individuals of these species are very abundant. Shell fragments, bone fragments and broken ostracode carapaces are also present. The new species of foraminifers introduced are:

Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. C
Hippocrepina sp. cf. H. barksdalei (Tappan)
Neobulimina canadensis Cushman and Wickenden
Nonionella taylorensis Hofker
Praebulimina carseyae (Plummer)
P. sp. cf. P. venusae (Nauss)
Saccammina sp. C
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides sp. A

Second depositional unit (108 feet thick):

The calcareous species are absent for the first 30 feet of this unit. The section is quite sandy, indicating a shallow inner sublittoral environment. Shell fragments, bone fragments, ostracode debris, and a few radiolarians are present. The arenaceous foraminiferal fauna is only moderately abundant. The species present are:

Haplophragmoides rota Nauss
H. sp. A
H. sp. C
Saccammina sp. B
Trochammina albertensis Wickenden
Verneuilinoides sp. cf. V. bearpawensis (Wickenden)

The next 50 feet of this unit show reintroduction of the calcareous fauna which becomes moderately abundant and suggests a return to possibly the outer sublittoral environment. Radiolarians, shell and bone fragments, a few teeth and some ostracode debris are also present. The foraminiferal species present are:

Anomalinoides talaria (Nauss)
Eoeponidella strombodes Tappan
Haplophragmoides rota Nauss
H. sp. A
Nonionella taylorensis Hofker
Saccammina lathrami Tappan
S. sp. A
S. sp. B
S. sp. C
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
?Valvulineria sp. A
Verneuilinoides sp. cf. V. bearpawensis (Wickenden)

The last 28 feet of this unit are quite unfossiliferous, containing only a few shell fragments, and numerous megaspores. The formation is quite sandy, indicating a return to inner sublittoral or littoral conditions.

Third deposition unit (115 feet thick):

A small number of arenaceous foraminifers are scattered sporadically through the first 37 feet of this unit, indicating very slow return of conditions suitable for benthonic fauna. Some bone fragments, pelecypod shells and ostracode fragments are present. The species of Foraminifera present are:

Haplophragmoides rota Nauss
Saccammina lathrami Tappan
S. sp. B
S. sp. D
Verneuilinoides sp. A

The next 40 feet of the interval indicates a return to a definite sublittoral environment. Shell and bone fragments are present, as well as some ostracode debris. Individuals of foraminiferal species are abundant. The foraminiferal species present are:

Anomalinoides talaria (Nauss)
Eoeponidella strombodes Tappan
Haplophragmoides rota Nauss
H. sp. A
H. sp. C
Hippocrepina sp. cf. H. barksdalei (Tappan)
Nonionella taylorensis Hofker
Quinqueloculina sphaera Nauss
Q. sp. A
Saccammina sp. B
Trochammina albertensis Wickenden
Verneuilinoides sp. cf. V. bearpawensis (Wickenden)
Verneuilinoides sp. A

The above fauna is abruptly replaced by deposition of the "Second Castor Sandstone" which is 38 feet thick. This sandstone may indicate some tectonic movement.

Fourth depositional unit (125 feet thick):

The lower seven feet of this unit are barren of foraminiferal elements suggesting very slow advancement of the sea. Numerous megaspores are present.

Return of sublittoral depositional conditions is shown by the reintroduction of the faunal elements which characterized the formation below the "Second Castor Sandstone", and the introduction of one new arenaceous and two new calcareous species over the next 45 feet of the unit.

Pelecypod and bone fragments, and some ostracode debris are present. The foraminiferal species present in this interval are:

Anomalinoides talaria (Nauss)
?*Cassidella* sp. A
Dentalina basiplanata Cushman
Eoeponidella linki Wickenden
E. strombodes Tappan
Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. B
H. sp. C
Praebulimina carseyae (Plummer)
P. sp. cf. *P. venusae* (Nauss)
Saccammina lathrami Tappan
S. sp. A
S. sp. B
S. sp. C
S. sp. D
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

Over the next 15 feet this unit is very sandy, showing gradual shallowing of the sea, and becoming somewhat transitional to the base of the overlying "First Castor Sandstone". Pelecypod and ostracode fragments are present, and echinoid debris is very abundant. A very few *Saccammina* spp. C and D are present.

The fourth depositional unit ends with the 60 foot thick "First Castor Sandstone". Although Lines (1963) suggested that the uppermost sandstone member at Castor was nonmarine in origin no evidence for this statement was noted in the available core material. However, it is quite likely that this sandstone, at least in part, is nonmarine.

Fifth depositional unit (85 feet thick):

The first 23 feet of this unit indicate a final sudden

return to sublittoral conditions with the abrupt reintroduction of the faunal elements immediately above the top of the "First Castor Sandstone". Shell and bone fragments, ostracode debris and possible oligosteginids are present. Individuals of foraminiferal species are quite abundant in this interval and the species present are:

Ammodiscus sp. A
Anomalinoides talaria (Nauss)
?*Cassidella* sp. A
Haplophragmoides kirki Wickenden
H. rota Nauss
H. sp. cf. *H. collyra* Nauss
H. sp. A
H. sp. B
Heterohelix globulosa (Ehrenberg)
Praebulimina carseyae (Plummer)
P. sp. cf. *P. venusae* (Nauss)
Saccammina sp. A
S. sp. B
S. sp. C
S. sp. D
Trochammina albertensis Wickenden
Valvulineria loetterlei (Tappan)
Verneuilina sp. A
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

The only planktonic foraminifer present in the Bearpaw Formation from the Castor section, *Heterohelix globulosa* (Ehrenberg), was recovered near the top of this interval. The presence of this species may be accounted for by current action bringing it from further south, but the fact that planktonic foraminifers are also recovered from the upper Bearpaw Formation at Bassano and Dorothy suggests that the water may have been approaching its greatest depth at this time of deposition.

The next 37 feet of this unit contain a moderate number of individuals of solely arenaceous species, as well as bone

fragments, ostracode fragments, some teeth and possible oligosteginids. This interval indicates the gradual shallowing of the sea for the last time. The foraminiferal species present are:

- *Haplophragmoides kirki* Wickenden
- *H. rota* Nauss
- *H.* sp. cf. *H. collyra* Nauss
- *H.* sp. A
- *H.* sp. B
- *H.* sp. C
- *Saccammina lathrami* Tappan
- *S.* sp. B
- *S.* sp. C
- *Trochammina albertensis* Wickenden
- *Verneuilina* sp. A
- *Verneuilinoides* sp. cf. *V. bearpawensis* (Wickenden)

The last 25 feet of this upper unit of the Bearpaw Formation contain only a few scattered individuals of *Haplophragmoides rota* Nauss and *Dentalina basiplanata* Cushman. Bone and pelecypod fragments, ostracode debris, and numerous megaspores are present. The formation is becoming sandier and transitional to the base of the overlying Edmonton Formation. The abundant megaspores and disseminated carbonaceous material present indicate nearshore conditions.

Bow City Locality (JW 66-18)

The Bow City section illustrates the first transgression and deepening of the Bearpaw Sea which has been seen from the Castor section. This section generally contains very much less plant debris and megaspores material than the Castor section.

The first 32 feet of the Bow City section are marked by the immediate introduction of an arenaceous fauna in which individuals of species are very numerous within five feet of the base of the formation. As judged from the more numerous species and individuals present at the base of this section, transgression was more rapid here, and the marine conditions somewhat more favorable for the large population of individuals found in this section. A few bone and pelecypod fragments are present. The foraminiferal species present are:

- *Ammodiscus* sp. A
- *Haplophragmoides kirki* Wickenden
- *H. rota* Nauss
- *H.* sp. A
- *H.* sp. C
- *Hippocrepina* sp. cf. *H. barksdalei* (Tappan)
- *Saccammina* sp. A
- *S.* sp. B
- *S.* sp. C
- *Textularia gravenori* Stelck and Wall
- *Trochammina albertensis* Wickenden
- *Verneuilina* sp. A
- *Verneuilinoides bearpawensis* (Wickenden)

The next 13 feet of the unit show the sudden introduction of a very abundant calcareous fauna as well as continuance of the previous arenaceous faunal elements. A few spores, some bone and pelecypod fragments, echinoid debris and some possible oligosteginids are present.

This interval is considered to be the same as the basal calcareous faunal interval from the Castor section. The fact that there is one species of planktonic Foraminifera present in the Bow City section, and that some calcareous individuals attain a very large size indicates that the water in the more southern section was somewhat deeper than at Castor, and was

probably definitely within the outer sublittoral zone. The new species of Foraminifera introduced in this interval are:

Anomalinoides talaria (Nauss)
Dentalina basiplanata Cushman
Eoeponidella linki Wickenden
Heterohelix globulosa (Ehrenberg)
Neobulimina canadensis Cushman and Wickenden
Praebulimina sp. cf. *P. venusae* (Nauss)
Saccammina lathrami Tappan
Valvulineria loetterlei (Tappan)

The last 65 feet of this unit are characterized by the arenaceous species of Foraminifera present in the basal portion of the Bow City section. Only *Haplophragmoides kirki* Wickenden is missing from the upper part of the interval. A few bone fragments and radiolarians, and some possible oligosteginids are also present. This interval probably represents inner to outer sublittoral zone conditions, but the environment was unsuitable for calcareous species.

Bassano Locality (JW 66-17)

This section comprises the upper 92 feet of the Bearpaw Formation and illustrates the final deepening of the sea which was noted from the Castor section.

The basal 32 feet of the Bassano section contain some megaspores, teeth and echinoid debris. Only a sparse arenaceous foraminiferal fauna is present. The uppermost seven feet of this interval contain the greatest species diversification suggesting rather gradual deepening of the sea and the development of a more favorable environment after a previous

episode of shallowing. The species present are:

> Haplophragmoides kirki Wickenden
> H. rota Nauss
> H. sp. cf. H. collyra Nauss
> H. sp. B
> Hippocrepina sp. cf. H. barksdalei (Tappan)
> Saccammina sp. B
> Verneuilina sp. A
> Verneuilinoides sp. cf. V. bearpawensis (Wickenden)

The middle 30 feet of this unit show an apparent increase in the depth of water to some part of the sublittoral zone, as several species of calcareous foraminifers are introduced, including two species of planktonic Foraminifera. The presence of these plankton suggests that this interval is correlative with the 23 foot section (or some part of it) from the Castor well which contains abundant calcareous individuals and Heterohelix globulosa (Ehrenberg). A few pelecypod shells are also present. The foraminiferal species present are:

> ?Cassidella sp. A
> Globigerinelloides aspera (Ehrenberg)
> Haplophragmoides rota Nauss
> H. sp. B
> Heterohelix globulosa (Ehrenberg)
> Hippocrepina sp. cf. H. barksdalei (Tappan)
> Nonionella taylorensis Hofker
> Praebulimina carseyae (Plummer)
> Quinqueloculina sphaera Nauss
> Valvulineria loetterlei (Tappan)

Over the last 30 feet this unit is very sandy and becomes transitional with the base of the overlying Edmonton Formation. The sample above the previous interval contains Haplophragmoides rota Nauss and ?Cassidella sp. A, and a single sample taken immediately below the Edmonton Formation contact contained Saccammina sp. B, indicating very shallow

water conditions probably prevailed during this last 30 foot interval. Some echinoid debris and numerous megaspores were also recovered from these samples.

Dorothy locality (MG 68-3 and 4)

The Dorothy sections are generally more weathered than the other outcrop samples used in this thesis. Thus, the sections undoubtedly cannot be considered truly representative of the Bearpaw Formation in this region. However, it is possible to recognize one deepening of the sea in the Dorothy section which is probably correlative with the final deepening noted from the Castor well, and the Bassano outcrop locality.

The lowermost 32 feet of the Dorothy section contain a few bone fragments, some megaspores, and a sparse arenaceous foraminiferal fauna in the basal 22 feet. The section is completely barren and quite sandy, grading into the overlying sandstone interval for the last ten feet of the interval. This unit may represent the shallowing of a previous depositional cycle (perhaps the fourth at Castor). The foraminiferal species present are:

Haplophragmoides rota Nauss
Saccammina sp. A
S. sp. B
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

The "Dorothy Sandstone" comprises the next 22 feet of the section. This sandstone does not appear to be correlative with any of the sandstones present in the Castor section, and

therefore most probably represents a strictly local bar type of deposit.

Upper deposition unit (178 feet thick):

The first 37 feet of this interval contain megaspores, teeth, pelecypod fragments, and some possible oligosteginids. A moderately abundant arenaceous foraminiferal fauna is present with individuals being generally extremely coarse grained, probably reflecting the sandy nature of the depositional environment. The species present are:

<u>Haplophragmoides</u> <u>rota</u> Nauss
<u>H</u>. sp. cf. <u>H</u>. <u>collyra</u> Nauss
<u>H</u>. sp. B
<u>H</u>. sp. C
<u>Saccammina</u> sp. A
<u>S</u>. sp. B
<u>S</u>. sp. D
<u>Verneuilina</u> sp. A
<u>Verneuilinoides</u> sp. cf. <u>V</u>. <u>bearpawensis</u> (Wickenden)

The "Dorothy Bentonite" comprises the next 30 feet of the unit and may, in part, be correlative with the "First Castor Sandstone". The magnitude of this bentonite indicates either enormous or prolonged volcanic activity. With vulcanism being known from the Cordilleran region several hundred miles to the south and west of Dorothy during Bearpaw time, some sort of dominant wind direction or jet stream type of atmospheric current must have transported this volcanic ash to the Dorothy area.

The next 36 feet of the unit contain only a few individuals of <u>Haplophragmoides</u> <u>rota</u> Nauss, <u>Saccammina</u> sp. C and <u>Anomalinoides</u> <u>talaria</u> (Nauss). Some shell fragments, echinoid debris, and megaspores are also present. The effects of the

underlying volcanic ash cannot be disregarded in making the environment very unsuitable for foraminiferal life, and the depth of water of deposition for this interval is probably greater than would be suggested from the meager faunal record.

A definite deepening of the sea is detected from the next three foot interval, which contains three calcareous foraminiferal species including a planktonic form. This faunal interval may well have been much more extensive than is apparent from the present collections, and undoubtedly is correlative with some part of the final depositional unit noted from the Castor well, and the Bassano locality as all these units contain an interval marked by calcareous foraminifers and planktonic forms. The species present are:

?*Cassidella* sp. A
Globigerinelloides aspera (Ehrenberg)
Nonionella taylorensis Hofker
Valvulineria loetterlei (Tappan)

The last 72 feet of the Bearpaw Formation exposed at Dorothy contain only a few arenaceous individuals. The species present are:

Haplophragmoides rota Nauss
H. sp. A
Saccammina sp. A
S. sp. C
Verneuilinoides sp. cf. *V. bearpawensis* (Wickenden)

Megaspores, shell and bone fragments, and abundant echinoid debris are present in this interval. The interval becomes extremely sandy in places, and is transitional with the overlying base of the Edmonton Formation. The depositional depth

of water probably varied between inner sublittoral and littoral at this time, with nearshore conditions dominating through most of the interval.

CHAPTER FIVE - CORRELATION OF THE BEARPAW FORMATION

Based on the faunal evidence, the Bearpaw Formation recovered from the Castor well core appears to be the equivalent of the middle to upper half of the Manyberries Member of the Bearpaw Formation which was described from southern Alberta. The proposed faunal correlation of the Bearpaw Formation from the Castor well with faunal zones of northern Alaska and Saskatchewan is illustrated in figure 8.

Loranger and Gleddie (1953) have described five microfaunal zones from their sections of the Bearpaw Formation in the Cypress Hills region. In ascending order, these are a *Tritaxia* Zone (260 feet thick), a *Plectina* Zone (150 feet thick), an *Anomalina* Zone (240 feet thick), an *Ammodiscus* Zone (180 feet thick), a barren zone (40-80 feet thick), and a *Gyroidina* and Ostracoda Zone (140 feet thick). The Bearpaw Formation in central southeastern Alberta contains a number of genera which are present in the lower three zones. As the genus *Anomalinoides* is quite abundant in the Castor section, this may suggest a stronger correlation with the upper *Anomalina* Zone than with the basal *Tritaxia* Zone. If this correlation is valid, it would indicate some diachroneity of the lower Bearpaw Formation boundary in central southeastern Alberta.

Caldwell and North (1964) have indicated three microfaunal assemblage zones for the Bearpaw Formation in the

<table>
<tr><th>Sentinel Hill Member of Schrader Bluff Formation of northern Alaska (Bergquist, 1956)</th><th>Bearpaw Formation of Castor, Alberta</th><th>Bearpaw Formation of South Saskatchewan River valley, (Caldwell and North, 1964)</th><th>Bearpaw Formation of southwestern Saskatchewan and southeastern Alberta (Loranger and Gleddie, 1953)</th></tr>
<tr><td rowspan="5"></td><td rowspan="3"></td><td rowspan="4">Haplophragmoides excavata Zone</td><td>Gyroidina and Ostracode Zone</td></tr>
<tr><td>Glauconitic Zone</td></tr>
<tr><td rowspan="2">Ammodiscus Zone</td></tr>
<tr><td rowspan="2">?Cassidella sp. A "Zone"</td></tr>
<tr><td rowspan="2">Anomalinoides henbesti Zone</td><td rowspan="2">Anomalina Zone</td></tr>
<tr><td rowspan="3">Eoeponidella strombodes Zone</td><td rowspan="3">Eoeponidella strombodes Zone</td></tr>
<tr><td>"barren" interval</td><td rowspan="3">Plectina Zone</td></tr>
<tr><td rowspan="3">Gaudryina sp. Zone</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td rowspan="2">Tritaxia Zone</td></tr>
<tr><td>not sampled</td></tr>
</table>

Figure 8. Correlation of Bearpaw Formation Microfaunal Zones from Alberta and Saskatchewan with Sentinel Hill Member Microfaunal Zone of Alaska.

South Saskatchewan River valley. In descending order these zones are the *Haplophragmoides excavata* Zone (300 feet thick), the *Anomalinoides henbesti* Zone (240 feet thick), a barren interval (100 feet thick) and a *Gaudryina* sp. Zone (150 feet thick, the lowermost 130 feet of the formation was not sampled.

Wall (1967) has pointed out that *Anomalinoides henbesti* from the Dowling Member of the Wapiabi Formation in the Foothills region of Alberta includes transitional forms which resemble *Anomalinoides talaria*. The abundance of *A. talaria* in the Bearpaw Formation from central southeastern Alberta may indicate a stronger correlation with the *A. henbesti* Zone than with the lower *Gaudryina* sp. Zone of Caldwell and North. This would again suggest some diachroneity of the lower Bearpaw Formation boundary in the thesis area.

Recent personal communication with Cadlwell and North has established the actual diachroneity of the lower Bearpaw Formation boundary. Approximately 400 feet of extra section is present in the basal Bearpaw Formation of the South Saskatchewan River valley when this area is compared with the Alberta plains region. The apparent faunal similarity between the Bearpaw Formation of central southeastern Alberta and the *Anomalinoides henbesti* Zone is better established. Many species are common to the two areas. The taxa designated as ?*Valvulineria* sp. A from the basal Bearpaw Formation at Castor is restricted to the middle Bearpaw Formation in Saskatchewan. An interval of planktonic foraminifers present in the upper portion of the

A. henbesti Zone may be correlative with the occurrence of such forms in the upper Bearpaw Formation of the thesis area. The occurrence of *E. linki* only in the Saskatchewan section, and of *E. strombodes* with only a few *E. linki* in the Alberta sections suggests these are facies sensitive forms. Many more calcareous species and a more diversified fauna suggest that the Saskatchewan section was deposited in substantially deeper water than was true for the central southeastern region of Alberta.

Caldwell and North (1964) state that there is no faunal similarity between the Bearpaw Formation of Saskatchewan and the Sentinel Hill Member of the Schrader Bluff Formation of northern Alaska, and they compare the Sentinel Hill fauna with the upper Lea Park and lower Belly River faunas of western Saskatchewan and eastern Alberta. They compare the Saskatchewan Bearpaw fauna with the higher formations of the Gulf Series.

The microfauna from the Bearpaw Formation in central southeastern Alberta does not show much affinity to the Gulf Coast forms other than the presence of older Lea Park species which appear to have migrated from the southern sea. The microfaunas of the Bearpaw Formation in central southeastern Alberta, the Sentinel Hill Member of northern Alaska, and the Lea Park Formation of eastern Alberta and western Saskatchewan are closely related. The general lack of calcareous species and the dominance of arenaceous species in the Bearpaw Formation of southeast central Alberta indicates that

environmentally tolerant Lea Park forms were able to cope with the fluctuating relatively shallow water environments of Bearpaw time in central southeastern Alberta.

Similar environmental conditions may explain the resemblance of the Sentinel Hill Member fauna to the Bearpaw Formation fauna in the thesis area. Tappan (1960) stated that the arenaceous species which dominate the Alaskan sections tend to be long-ranging and environmentally tolerant species, and that most of the Cretaceous strata of northern Alaska are apparently nonmarine and nearshore deposits intertonguing with marine strata, thus causing rapid changes in depositional environments laterally as well as with time. She considered the Sentinel Hill Member to represent variation from the inner to outer sublittoral region with calcareous species of Foraminifera being more developed in the outer sublittoral region.

The microfauna of the Bearpaw Formation in the thesis area is related to the Eoeponidella strombodes Zone of Bergquist (1956), or the subzone Tappan (1960) stated could be defined from the Trochammina ribstonensis-Neobulimina canadensis Zone for the Sentinel Hill Member of the Schrader Bluff Formation in northern Alaska. Even allowing for what appears to be the questionable identification of Haplophragmoides rota Nauss, the normal tendency to transfer names of species from one region to another, and Bergquist's (1966) disagreements concerning faunal ranges in the Schrader Bluff Formation, three major areas of faunal similarity between the Sentinel

Hill Member and the Bearpaw Formation of the thesis area are present.

Both contain a number of species of Lea Park Formation Foraminifera which may be explained by the Wapiabi or Milk River Sea connection between Alaska and western Canada.

An extensive radiolarian fauna is reported by both Tappan (1960) and Bergquist (1966) in the lower part of the Sentinel Hill Member, and radiolarians, although not abundant, are seemingly present in the Bearpaw Formation of central southeastern Alberta. Bergquist (1966) states that very few radiolarian faunas have been described from the Cretaceous rocks of North America. Unfortunately, the Bearpaw specimens are pyritized and not easily compared with any others for more complete identification.

The third faunal similarity between the Sentinel Hill Member and the Bearpaw Formation is the presence in both of two species of the genus Eoeponidella Wickenden.

These faunal similarities between the Alaskan Sentinel Hill Member and the Bearpaw Formation of the thesis area tend to indicate an open marine connection allowing for at least the nearshore migration of environmentally tolerant forms during some part of Bearpaw time. The fact that Eoeponidella strombodes is not reported from any sections other than the Bearpaw Formation of the Castor well and the Sentinel Hill Member of northern Alaska tends to support this idea.

CHAPTER SIX - CONCLUSIONS

The fauna recovered from the Bearpaw Formation in central southeastern Alberta is an undiversified, long-ranging fauna reflecting environmental control. The foraminiferal species are largely descended from the older Lea Park Formation faunas of east-central Alberta and west-central Saskatchewan.

Strong similarity of the faunal components present in the Bearpaw Formation in the thesis area with those of the Sentinel Hill Member of the Schrader Bluff Formation of northern Alaska is also noted. This may indicate similarity of environment of deposition. However, the possibility of a marine connection existing through northern Saskatchewan to northern Alaska for some part of Bearpaw time is not to be discounted.

Zonation of the foraminiferal elements of the Bearpaw Formation in central southeastern Alberta is somewhat tentative due to the long-ranging natureof the fauna. An *Eoeponidella strombodes* Zone is named for the lower two-thirds (312 feet) of the Bearpaw Formation from the Castor well. The upper one-third (158 feet) of the formation appears to be characterized only by ?*Cassidella* sp. A.

Using the relationship of the proportion of calcareous benthonic to arenaceous Foraminifera, the depth of water of deposition for the Bearpaw Formation sediments is judged to be chiefly sublittoral with possible littoral deposition being reflected by some of the sandstone members.

Five cycles of fluctuation of water depth may be seen from the faunal record present in the Bearpaw Formation from the Castor well.

The primary deepening of the water at Castor is correlated with a similar primary deepening noted from the Bow City section. The last deepening noted at Castor is also seen in the Bassano and Dorothy sections. The sediments deposited in this episode of deepening contain, at all three localities, most of the planktonic Foraminifera recovered from the Bearpaw Formation in the thesis area. This either indicates a change in the dominant current directions bringing the planktons from much further south, or else is an indication that the water was somewhat deeper at this time than is apparent from any other portion of the section.

The lowermost boundary of the Bearpaw Formation in the thesis area appears to be slightly diachronous moving northward from the Bow City section to Castor.

On the basis of comparison with microfaunal assemblage zones proposed by Loranger and Gleddie (1953) and North and Caldwell (1964), the Bearpaw Formation in central southeastern Alberta is considered to represent some part of the middle to upper half of the Manyberries Member proposed by Lines (1963) for the lower half of the Bearpaw Formation in southern Alberta. The better correlation with the higher *Anomalina* and *Anomalinoides henbesti* Zones again indicates diachroneity of the lower Bearpaw Formation boundary moving from southern Saskatchewan and southeastern Alberta to the thesis area.

From the available Bearpaw Formation samples, it is quite readily apparent that central southeastern Alberta, and especially the Castor area, is very close to what must have been the shoreline of the Bearpaw Sea. The numerous sandstones present in the sections do not readily correlate with each other, or with any of the described sandstone members from the southern Bearpaw sections. These sandstones are apparently very local units, probably of bar or shoal origin.

The enormous bentonite seam present from the Dorothy section, which may be correlative with some part of the "First Castor Sandstone", alone denotes the active vulcanism from the Cordilleran region to the west. However, there is much montmorillonitic type of material disseminated throughout the Bearpaw Formation samples processed for microfauna, and a number of small bentonite seams up to a few inches thick have been noted. All these findings are indicative of the growing tectonic activity to the west of the sea which ultimately raised a land surface above the Bearpaw Sea.

CHAPTER SEVEN - SYSTEMATIC DESCRIPTIONS

Introduction

For the following systematic descriptions, the designation of generic and higher rank taxa follows exclusively the classification of Loeblich and Tappan (1964). Taxa of rank lower than genera have been designated by three methods. Nineteen specimens are described as hypotypes of previously published species and four as sp. cf. previously published species.

Thirteen groups were distinguished from published species and have been identified by letters. For the purposes of this thesis it has not been deemed advisable to define any of these groups as new species at this time. In some instances too few individuals are present for definition of a population. Preservation is frequently so poor that morphologic details are obscured, and even the generic assignment may be questioned. Any names proposed in this thesis would not be valid and, in any case, all names proposed by North and Caldwell (in press) would have priority.

Arenaceous Foraminifera dominate the microfaunal content of the Bearpaw sections in the present study. Seven arenaceous families accout for 20 species, whereas nine calcareous families are represented by 16 species. The

most important, numerically, of these families are the arenaceous Astrorhizidae, Saccamminidae, Lituolidae and Ataxophragmiidae; and the calcareous Turrilinidae, Discorbidae and Anomalinidae.

Twelve groups of microfauna which are not foraminifers have been included in the systematic descriptions. Six of these groups have been considered to belong to the Subclass Radiolaria Muller, 1858. Six groups are categorized as _incertae sedis_. One of these latter is probably a radiolarian. The others are calcareous spheres which may belong to the oligosteginid genus _Calcisphaerula_ Bonet, 1956 (Adams, Khalili and Said, 1967).

Explanation of the numerical designation of figured specimens and collecting localities have been included in the Introduction, and all samples are described in the Appendix.

Phylum PROTOZOA

Subphylum SARCODINA Schmarda, 1871

Class RETICULAREA Lankester, 1885

Subclass GRANULORETICULOSIA de Saedeleer, 1934

Order FORAMINIFERIDA Eichwald, 1830

Suborder TEXTULARIINA Delage and Herouard, 1896

Superfamily AMMODISCACEA Reuss, 1862

Family ASTRORHIZIDAE Brady, 1881

Subfamily RHIZAMMININAE Rhumbler, 1895

Genus BATHYSIPHON M. Sars, 1872

BATHYSIPHON VITTA Nauss

Pl. I, fig. 1.

Bathysiphon vitta Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334, pl. 48, fig. 4; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 128-129, pl. 29, figs. 6-8; Graham and Church, 1963, Stanford Univ. Pubs. Geol. Sci., vol. 8, no. 1, p. 17-18, pl. 1, figs. 1-2; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 10-11, pl. 1, fig. 1; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 38, pl. 7, figs. 4-7.

Description: Test tubular, rounded, wrinkled growth lines or constrictions; fine grained (0.02 mm. diameter), some angular grains; wall relatively thick, white, siliceous; inner portion of wall with less cement than external wall leaving the grains on the surface remote from each other,

but not projecting; aperture formed by open ends of tube.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 1	0.75	0.53

Location: Hypotype MG 1 is from the middle Bearpaw Formation, sample B.G. 1, 106-108 feet below the ground level.

Distribution: Bathysiphon vitta Nauss has been reported from the Lea Park Formation of east-central Alberta and western Saskatchewan, and the Wapiabi Formation of the Foothills of Alberta. The latter occurrence is at a lower stratigraphic level than the type occurrence. In California, the species has been reported from beds ranging in age from Turonian to Campanian. The Alaskan occurrences of this species are from the Albian Grandstand and Topagoruk Formations.

The occurrence of this species in the thesis area ia restricted to the two isolated corehole samples obtained near the twon of Big Stone.

Remarks: These specimens lack the dark material on the outside of the test of the holotype. The figured specimen has been compressed.

Subfamily HIPPOCREPININAE Rhumbler, 1895

Genus HIPPOCREPINA Parker, 1870

HIPPOCREPINA sp. cf. H. BARKSDALEI (Tappan)

Pl. I, fig. 4.

?*Hyperamminoides barksdalei* Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 129-130, pl. 29, figs. 21-27.

Description: Test a single spindle-shaped chamber, flaring out towards apertural end which becomes constricted; some constrictions which may represent growth lines; fine grained (0.01 mm. diameter); aperture round, terminal on short neck.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 2	0.50	0.25

Location: Figured specimen MG 2 is from the Castor well, 435 feet below the top of the Bearpaw Formation.

Distribution: This form apparently ranges throughout the Bearpaw Formation, as it is present in the basal part of the formation at Castor, and the Bow City locality, and in the upper part of the formation at the Bassano locality.

Remarks: The present material is coarser grained and more pointed at the apertural end than the species *Hippocrepina*

barksdalei (Tappan) from the Albian of Alaska.

The figured specimen has been crushed and gives a slight suggestion of a *Miliammina*.

Family SACCAMMINIDAE Brady, 1884

Subfamily SACCAMMININAE Brady, 1884

Genus SACCAMMINA M. Sars, 1869

SACCAMMINA LATHRAMI Tappan

Pl. I, fig. 6.

Saccammina lathrami Tappan, 1960, Bull. Am. Assoc. Petroleum Geol., vol. 44, no. 3, p. 289, pl. 1, figs. 1-2; Tappan, 1962, U. S. Geol. Surv. Prof. Paper 236-C, p. 129, pl. 29, fig. 11; *non* figs. 9-10, 12.

Description: Test a single chamber, oval, slightly pyriform; center depressed, slightly darker colored; wall fine grained (0.01 mm. diameter), smooth, with much cement, white; aperture terminal on a short, wide, neck-like structure.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)
Hypotype MG 3	0.35	0.27

Location: Hypotype MG 3 is from the Castor well, 42 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from northern Alaska in strata ranging in age from Albian to Turonian.

The species is present throughout the Castor section of the Bearpaw Formation, and it also appears in the basal part of the formation at the Bow City locality.

Remarks: Saccammina lathrami Tappan is similar to S. complanata (Franke), but it is smaller with a relatively larger through less distinctly defined neck.

SACCAMMINA sp. A

Pl. I, figs. 12, 13.

Description: Test large, round, single chamber; crushed, large central depression on one side; very angular coarse grains (0.18 mm. maximum diameter); surface rough; short neck; aperture not seen.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)
Figured specimen MG 4	0.88	0.75
Figured specimen MG 5	1.05	0.88

Location: Figured specimen MG 4 is from the Castor well, 81 feet below the top of the Bearpaw Formation.

Figured specimen MG 5 is from the middle Bearpaw Formation, sample B.G. 1, 106-108 feet below the ground level.

Distribution: This form ranges through most of the Bearpaw Formation from the Castor well. It is found at all the collecting localities except Bassano.

Remarks: The Saccammina sp. 1 figured by Wall (1967) from the transition beds of the Wapiabi Formation in the Foothills of Alberta appears very similar to the present specimens, however, the latter are larger and more coarsely grained.

SACCAMMINA sp. B

Pl. I, fig. 5.

Description: Test generally round, flattened; may or may not have a central depression; medium grained (0.02 mm. diameter); no aperture seen.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)
Figured specimen MG 6	0.40	0.10

Location: Figured specimen MG 6 is from the Castor well, 35.5 feet below the top of the Bearpaw Formation.

Distribution: This form ranges through the entire Bearpaw Formation, and is abundantly present at all the collecting localities.

Remarks: Saccammina sp. B is very similar to S. sp. C but

the former is consistently larger, coarser grained and has a rougher surface texture.

SACCAMMINA sp. C

Pl. I, figs. 7, 8.

Description: Test generally small, round to oval, flattened; may or may not have a central depression; smooth, very fine grained (0.005 mm. diameter); no aperture seen.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)
Figured specimen MG 7	0.18	0.05
Figured specimen MG 8	0.27	0.05

Location: Figured specimen MG 7 is from the Castor well, 49 feet below the top of the Bearpaw Formation.

Figured specimen MG 8 is from the Castor well, 55.5 feet below the top of the Bearpaw Formation.

Distribution: This form ranges through the entire Bearpaw Formation and is abundant at all localities, with the exception of Bassano, where it does not occur.

Remarks: The Saccammina sp. figured by Stelck, Wall and Wetter (1958, p. 31, pl. 4, fig. 11) from the upper St. John Shale in northeastern British Columbia is very similar

in size of test, grain size and smooth surface to the present group. The lack of distinctive morphologic features makes differentiation of these species of Saccammina very difficult.

The surface texture and grain size of S. sp. C is very similar to that of S. lathrami Tappan, however, Saccammina sp. C is consistently smaller than S. lathrami and no neck is developed.

SACCAMMINA sp. D

Pl. I, figs. 2, 3.

Description: Test moderately large, single chamber, widest at base, sides tapering to apertural end with a definite neck developed; variable grain size (0.01-0.03 mm. diameter), larger grains absent on neck; rough surface; aperture terminal, round, may appear slit-like on flattened specimens.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 9	0.92	0.43
Figured specimen MG 10	0.85	0.40

Location: Figured specimen MG 9 is from the Castor well, 152 feet below the top of the Bearpaw Formation.

Figured specimen MG 10 is from the Castor well, 305.5 feet below the top of the Bearpaw Formation.

Distribution: This form is found in the upper 300 feet of the Bearpaw Formation from the Castor well. It is also present in the upper Bearpaw Formation from the Dorothy locality and was not found at the other collecting localities.

Remarks: The present specimens resemble S. alexanderi (Loeblich and Tappan) in general configuration. However, they are much larger, less coarsely grained and have better definition of the neck.

Family AMMODISCIDAE Reuss, 1862

Subfamily AMMODISCINAE Reuss, 1862

Genus AMMODISCUS Reuss, 1862

AMMODISCUS sp. A

Pl. I, fig. 11.

Description: Test small, compressed; proloculus and second chamber of about five to six volutions; width of tube increases slightly throughout length; slight suggestion of constrictions of the second chamber; wall smoother, white, often pyritized; aperture terminal.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 11	0.22	0.22	0.05

Location: Figured specimen MG 11 is from the Castor well, 55.5 feet below the top of the Bearpaw Formation.

Distribution: This form is present only in the uppermost Bearpaw Formation from the Castor well, and the lowermost part of the formation from the Bow City locality.

Remarks: The few specimens in the present study are relatively small and have fewer volutions of the second chamber than does Ammodiscus cretaceus (Reuss).

Family LITUOLIDAE de Blainville, 1825

Subfamily HAPLOPHRAGMOIDINAE Maync, 1952

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES KIRKI Wickenden

Pl. I, fig. 9.

Haplophragmoides kirki Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 85-86, pl. 1, figs. 1 a-c; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 21-22, pl. 2, figs. 23 a-c; Wall, 1960, Res. Coun. Alberta Bull. 6, p. 18, pl. 3, figs. 11-12; pl. 4, figs. 10-11; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 13, pl. 1, fig. 8.

Description: Test small to medium size, planispiral, involute; chambers of uniform size in final whorl; four and one-half to five chambers in final whorl; sutures straight, depressed; variable grain size (0.02 mm. diameter maximum); angular grains embedded in much arenaceous cement; grey-

white; aperture a low arch at base of terminal face.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 12	0.32	0.27	0.12

Location: Hypotype MG 12 is from the Castor well, 77.5 feet below the top of the Bearpaw Formation.

Distribution: The holotype is from the Bearpaw Formation of southern Alberta. The species has also been reported from the Lea Park and Pakowki Formations of Alberta and Saskatchewan, and the Riding Mountain Formation of Manitoba. A few scattered occurrences of H. kirki have been reported from the older Kaskapau and Puskwaskau Formations of the Smoky River area, Alberta.

This species ranges throughout the Bearpaw Formation from the Castor well. It is also found at the Bassano and Bow City localities.

Remarks: Individuals of H. kirki Wickenden from the Bearpaw samples of the present study are often partially pyritized.

HAPLOPHRAGMOIDES ROTA Nauss

Pl. I, figs. 10, 14, 16-19.

Haplophragmoides rota Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 339, pl. 49, figs. 1, 3; North and Caldwell, 1964,

Saskatchewan Res. Coun. Rept. 5, p. 13, pl. 1, fig. 11.

non Haplophragmoides rota Nauss. Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 134-135, pl. 31, figs. 16-18.

Description: Test medium size, planispiral, involute with a slight tendency to become evolute; rounded periphery; chambers of nearly equal size, inflated, triangular in outline; seven to ten in final whorl, commonly eight; sutures somewhat indistinct, radial, straight, not depressed; wall formed of a mosaic of grains (0.04 mm. diameter) in a moderate amount of cement; surface moderately rough; aperture obscured generally, low arch at base of terminal face.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 13	0.68	0.53	0.25
Hypotype MG 14	0.37	0.35	0.10
Hypotype MG 15	0.50	0.40	0.20
Hypotype MG 16	0.68	0.57	0.18
Hypotype MG 17	0.53	0.47	0.12
Hypotype MG 18	0.32	0.27	0.08

Location: Hypotype MG 13 is from the Castor well, 22 feet below the top of the Bearpaw Formation.

Hypotype MG 14 is from the Castor well, 32 feet below the top of the Bearpaw Formation.

Hypotype MG 15 is from the Castor well, 35.5 feet below the top of the Bearpaw Formation.

Hypotype MG 16 is from the Castor well, 49 feet below the top of the Bearpaw Formation.

Hypotype MG 17 is from the Castor well, 77.5 feet below the top of the Bearpaw Formation.

Hypotype MG 18 is from the Castor well, 202 feet below the top of the Bearpaw Formation.

Distribution: The holotype is from the Grizzly Bear Shale of the Belly River Formation in east-central Alberta. The species has been reported from the Lea Park Formation of south-central Saskatchewan. Wall (1967) has figured *Haplophragmoides* sp. cf. *H. rota* Nauss from the Wapiabi Formation in the Foothills of Alberta which is a considerably earlier occurrence. The specimens figured by Tappan (1962) from the Alaskan Schrader Bluff and Seabee Formations do not appear to be *H. rota* Nauss.

This species is abundant throughout the Bearpaw Formation from all the collecting localities.

Remarks: This species shows great variation in both grain size and size of test. These variations are felt to be due primarily to ecological or environmental conditions. In samples from the more sandy portions of the Bearpaw Formation the grain size shows a marked coarsening. Hypotypes 17 and 18 illustrate the finer variants.

Crushed specimens may reveal the inflation of the chambers as an irregularity of the peripheral outline showing a

mimicry of Haplophragmoides collyra Nauss.

HAPLOPHRAGMOIDES sp. cf. H. COLLYRA Nauss

Pl. I, figs. 21, 24.

?Haplophragmoides collyra Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 337-338, pl. 49, figs. 2, 5; Wall, 1960, Res. Coun. Alberta Bull. 6, p. 16-17, pl. 3, figs. 16-18; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 12, pl. 2, figs. 1 a-c.

Description: Test medium size, planispiral, involute; somewhat scalloped outline; generally found in collapsed condition; chambers of about uniform size, five to six in final whorl; sutures straight, ultimate and penultimate sutures depressed, other sutures flush; fine grained (0.01 mm. diameter); much white cement giving a smooth finish; aperture not seen.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 19	0.47	0.35	0.08
Figured specimen MG 20	0.35	0.27	0.05

Location: Figured specimen MG 19 is from the Castor well, 55.5 feet below the top of the Bearpaw Formation.

Figured specimen MG 20 is from the Castor well, 445.5 feet below the top of the Bearpaw Formation.

Distribution: This species was present in the basal Bearpaw Formation from the Castor and Bow City sections, and in the uppermost Bearpaw Formation from the Castor, Bassano, and Dorothy sections.

Remarks: These specimens are much like Haplophragmoides kirki Wickenden from the Bearpaw Formation, but they are very compressed, collapsed, somewhat larger, and finer grained. They have too few chambers to be directly assigned to Haplophragmoides collyra Nauss. The collapsed condition of the test and the very fine grain size suggest Haplophragmoides fraseri Wickenden, but the present specimens have too few chambers, do not appear to be evolute, and are larger.

HAPLOPHRAGMOIDES sp. A

Pl. I, figs. 20, 26.

Description: Test small to medium size, almost planispiral, last chamber slightly asymmetric with respect to plane of coiling; tiny umbilici developed; six to seven chambers in final whorl; chambers somewhat globular; sutures distinct, straight, radial, depressed; grain size 0.03 mm. diameter, but details masked by general pyritization; aperture a low arch at base of last formed chamber.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 21	0.45	0.37	0.12
Figured specimen MG 22	0.27	0.22	0.08

Location: Figured specimens MG 21 and MG 22 are from the Castor well, 42 feet below the top of the Bearpaw Formation.

Distribution: This form is present throughout the Bearpaw Formation from the Castor well, and is also present in the basal Bearpaw at Bow City, and the uppermost Bearpaw at the Bassano and Dorothy localities.

Remarks: *Haplophragmoides* sp. A could represent the pyritized partial internal mold of a form closely related to *H. kirki* Wickenden or *H.* sp. cf. *H. collyra* Nauss from the Bearpaw Formation.

HAPLOPHRAGMOIDES sp. B

Pl. I, fig. 22.

Description: Test very large, planispiral, compressed, lobate periphery; nine chambers in final whorl; sutures straight, indistinct, slightly depressed; medium to fine grained (0.06 mm. diameter); aperture a low arch at base of terminal face.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 23	1.39	1.25	0.37

Location: Figured specimen MG 23 is from the Castor well, 55.5 feet below the top of the Bearpaw Formation.

Distribution: This form occurs rarely in the uppermost Bearpaw Formation from the Castor well, the Bassano and Dorothy localities. It is also present from the basal Bearpaw Formation at Bow City.

Remarks: Haplophragmoides sp. B may well be a large variant of H. rota, ranging from 0.95 to 1.39 mm. in maximum diameter. If so, the inflation of the earlier chambers finally gains lobate expression in peripheral outline. Individuals of this group are relatively rare in the population, and may represent an ecologic variant reflecting delay in reproduction.

HAPLOPHRAGMOIDES sp. C

Pl. I, figs. 15, 23, 25.

Description: Test small, round, planispiral, somewhat flattened, evolute with proloculus visible; four to five whorls with seven to nine chambers in final whorl; eight commonly; sutures distinct, straight to slightly curved, slightly depressed, last two or three sutures slightly sigmoidal; medium to fine grained (0.01 mm. diameter); generally pyritized; aperture a low arch at base of terminal face.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 24	0.22	0.22	0.08
Figured specimen MG 25	0.30	0.25	0.10
Figured specimen MG 26	0.32	0.30	0.08

Location: Figured specimen MG 24 is from the Castor well, 22 feet below the top of the Bearpaw Formation.

Figured specimen MG 25 is from the Castor well, 250 feet below the top of the Bearpaw Formation.

Figured specimen MG 26 is from the Bow City section, JW 66-18, sample 4, 11 feet above the base of the Bearpaw Formation.

Distribution: A few individuals of this group range throughout the Bearpaw Formation from the Castor well. The form is also present in the uppermost Bearpaw from Dorothy and the basal Bearpaw from Bow City.

Remarks: *Haplophragmoides* sp. C resembles *H. howardense manifestum* Stelck and Wall, but it is more evolute and the chambers are less inflated. The present group also resembles *H. multiplum* Stelck and Wall but the latter has 12 to 14 chambers in the final whorl and is more inflated.

Family TEXTULARIIDAE Ehrenberg, 1838

Subfamily TEXTULARIINAE Ehrenberg, 1838

Genus TEXTULARIA Defrance, 1824

TEXTULARIA GRAVENORI Stelck and Wall

Pl. I, figs. 32, 33.

Textularia gravenori Stelck and Wall, 1955, Res. Coun. Alberta Rept. 70, p. 55, pl. 2, fig. 36; Tappan, 1962, U.S. Geol.

Surv. Prof. Paper 236-C, p. 141, pl. 33, figs. 16-17.

Description: Test small, elongate; seven to eight pairs of chambers; sutures distinct, depressed, oblique to long axis of test, zigzag in longitudinal median position; fine grained (0.01 mm. diameter); aperture a low arch at inner margin of last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 27	0.30	0.08
Hypotype MG 28	0.53	0.18

Location: Hypotype MG 27 is from the Bow City section, JW 66-18, sample 2, one foot above the base of the Bearpaw Formation.

Hypotype MG 28 is from the Bassano section, JW + MG, sample 1, 20 feet above the river.

Distribution: This species has been reported from the Turonian Seabee Formation of Alaska and the lower Kaskapau shale of northwestern Alberta.

In the present study, this species was only rarely encountered from the basal Bearpaw Formation at Bow City and the uppermost Bearpaw at Bassano.

Remarks: The present specimens are slightly larger than the holotype and appear to have fewer chambers.

Family TROCHAMMINIDAE Schwager, 1877

Subfamily TROCHAMMININAE Schwager, 1877

Genus TROCHAMMINA Parker and Jones, 1859

TROCHAMMINA ALBERTENSIS Wickenden

Pl. I, figs. 27, 28.

Trochammina albertensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 90, pl. 1, figs. 9 a-c; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 50, pl. 15, figs. 7 a-c; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 152-153, pl. 39, figs. 13-14.

Description: Test small to medium size, rounded periphery; trochospiral with moderate spire height, concave on umbilical side; two and one-half whorls of previous chambers visible on spiral side; four to five hemispherical chambers in final whorl; sutures well marked, slightly depressed, oblique, curved; fine grained (0.01 mm. diameter); aperture an arch opening into umbilicus.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 29	0.25	0.18	0.10
Hypotype MG 30	0.22	0.18	0.10

Location: Hypotype MG 29 is from the Castor well, 250 feet below the top of the Bearpaw Formation.

Hypotype MG 30 is from the Bow City section, JW 66-18,

sample 4, 11 feet above the base of the Bearpaw Formation.

Distribution: The holotype is from the Bearpaw Formation of southern Alberta. In Alaska, the species has been reported from the upper part of the Schrader Bluff Formation at about the same stratigraphic level as the holotype occurrence.

This species is abundant throughout the Bearpaw Formation from the Castor well and the basal part of the formation at the Bow City locality.

Remarks: Preservation generally gives the previous chambers of this species a dark reddish color.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEUILININAE Cushman, 1911

Genus VERNEUILINA d'Orbigny, 1839

VERNEUILINA sp. A

Pl. II, figs. 4-6.

Description: Test medium size, tapering towards base, sub-triangular in cross section; chamber size increasing moderately rapidly; six to seven whorls of chambers, which are globular in shape; sutures distinct, depressed; grain size variable (0.03 mm. diameter maximum); aperture an arch at inner margin of terminal chamber.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 31	0.63	0.25
Figured specimen MG 32	0.75	0.25
Figured specimen MG 33	0.45	0.20
Unfigured specimen MG 34	0.45	0.18

Location: Figured specimen MG 31 is from the Castor well, 35.5 feet below the top of the Bearpaw Formation.

Figured specimen MG 32 is from the Castor well, 81 feet below the top of the Bearpaw Formation.

Figured specimen MG 33 and unfigured specimen MG 34 are from the Bow City section, JW 66-18, sample 4, 11 feet above the base of the Bearpaw Formation.

Distribution: This form is present throughout the Bearpaw Formation, and is found at all localities.

Remarks: These specimens have one more whorl of chambers and are larger than the form figured by Wall (1967) as <u>Verneuilina canadensis</u> Cushman. The chambers do not overhang the edges of the test as they do in <u>V. canadensis</u> Cushman figured by Eicher (1960, 1965).

<u>Verneuilina</u> sp. A may represent the juvenile form of <u>Gaudryina bearpawensis</u> Wickenden. Wickenden (1932) stated that specimens of <u>G. bearpawensis</u> which show only the triserial portion may be confused with Verneuilina. Only a few specimens from the Bearpaw sections studied show a

slight tendency to become biserial and the initial biserial whorl is incomplete. Because these specimens are triserial they are more properly referred to the genus Verneuilina.

Genus VERNEUILINOIDES Loeblich and Tappan, 1949

VERNEUILINOIDES BEARPAWENSIS (Wickenden)

Pl. I, figs. 34, 35.

Verneuilina bearpawensis Wickenden, 1932, Trans. Roy. Soc. Can., 3rd ser., vol. 26, sec. 4, p. 87, pl. 1, fig. 8; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 31, pl. 7, figs. 4-6.

Verneuilinoides bearpawensis (Wickenden). Wall, 1960, Res. Coun. Alberta Bull. 6, p. 22-23, pl. 4, figs. 20-21; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 75, pl. 4, figs. 31-34; pl. 5, fig. 21; pl. 14, figs. 13-15.

Description: Test medium size, elongated; chamber arrangement buliminellid; four to five whorls of slightly inflated chambers; sutures oblique to long axis of test, distinct, slightly depressed; grain size fine (0.01 mm. diameter); aperture an arch at inner margin of last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 35	0.50	0.18
Hypotype MG 36	0.50	0.20

Location: Hypotypes MG 35 and MG 36 are from the Bow City section, JW 66-18, sample 2, one foot above the base of the Bearpaw Formation.

Distribution: The holotype is from the Bearpaw Formation of southern Alberta. The species is apparently long ranging in the Upper Cretaceous of Alberta as it has also been reported from the Lea Park Formation of the east-central portion of the province, the Puskwaskau Formation of the Smoky River area and from the Wapiabi and Blackstone Formations of the Foothills. The species has been reported from the Ripley Formation of Tennessee.

This species was only positively identified from the basal Bearpaw Formation at Bow City where it is very abundant.

Remarks: The present specimens are smaller than those figured by Wall (1967).

VERNEUILINOIDES sp. cf. V. BEARPAWENSIS (Wickenden)

Pl. I, figs. 29-31.

Description: Test medium size, compressed; small triserial portion flaring out to larger-chambered triserial portion; sutures apparently slightly depressed, oblique to long axis of test; medium grained (0.02 mm. diameter); aperture an arch at inner margin of last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 37	0.47	0.25
Figured specimen MG 38	0.45	0.25
Figured specimen MG 39	0.50	0.22

Location: Figured specimen MG 37 is from the Castor well, 70 feet below the top of the Bearpaw Formation.

Figured specimen MG 38 is from the Castor well, 424.5 feet below the top of the Bearpaw Formation.

Figured specimen MG 39 is from the Castor well, 449 feet below the top of the Bearpaw Formation.

Distribution: Individuals of this group are quite abundant throughout the Bearpaw Formation from the Castor well and the uppermost part of the formation from the Bassano and Dorothy localities.

Remarks: The figured specimens are often slightly smaller than V. bearpawensis (Wickenden). They are coarser grained, blunter at the initial end and their features are much less distinct.

Figured specimens 33 and 34 could represent the megalospheric stage and figured specimen 35 the microspheric stage.

VERNEUILINOIDES sp. A

Pl. II, figs. 1-3.

Description: Test elongated, tapering towards basal end; apparently triserial, slightly twisted; sutures defined, slightly depressed; very thin walled, collapsed; fine grained (0.01 mm. diameter); aperture broad, asymmetric arch.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 40	0.65	0.34
Figured specimen MG 41	0.63	0.27
Figured specimen MG 42	0.78	0.32
Figured specimen MG 43	0.40	0.30

Location: Figured specimens MG 40, MG 41, MG 42 and MG 43 are from the Castor well, 276.5 feet below the top of the Bearpaw Formation.

Distribution: This form was only present in the lower half of the Bearpaw Formation from the Castor well.

Remarks: Verneuilinoides sp. A may be a preservational or ecologic variant of V. sp. cf. V. bearpawensis (Wickenden) as they are never found together in these Bearpaw sections.

Suborder MILIOLINA Delage and Herouard, 1896

Superfamily MILIOLACEA Ehrenberg, 1839

Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA SPHAERA Nauss

Pl. II, fig. 10.

Quinqueloculina sphaera Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 340, pl. 48, figs. 14 a-c; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 157, pl. 37, figs. 6 a-c; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 17, pl. 3, figs. 1 a-c; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 86-87, pl. 6, figs. 16-18.

Description: Test small, broad, subspherical; four chambers visible on one side, three on other, inflated; sutures distinct, slightly depressed; wall brown, smooth, calcareous, porcellaneous; aperture terminal, U-shaped, on last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)	Thickness (mm.)
Hypotype MG 44	0.20	0.15	0.12

Location: Hypotype MG 44 is from the Bassano South section, JW 66-17, sample 9, 43 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from the Lea Park Formation in east-central Alberta and south-central Saskatchewan, and the Muskiki Member of the Wapiabi Formation in the Alberta Foothills. In Alaska, the species has been reported as occurring sporadically in the Schrader Bluff and Seabee Formations.

This species is rare in the Bearpaw Formation. It was found in the basal part of the formation at the Bow City locality, the middle part of the formation from the Castor well and the upper part of the formation at the Bassano locality.

Remarks: The figured specimen is slightly smaller than the holotype and the specimens figured by Tappan (1962) and Wall (1967).

QUINQUELOCULINA sp. A

Pl. II, fig. 11.

Description: Test long, narrow, oval outline; four chambers visible on one side, three on other, slightly inflated; sutures distinct, slightly depressed; wall smooth, calcareous, porcellaneous; aperture at end of last formed chamber.

Dimensions	Length (mm.)	Width (mm.)	Thickness (mm.)
Figured specimen MG 45	0.20	0.10	0.08

Location: Figured specimen MG 45 is from the Castor well, 283 feet below the top of the Bearpaw Formation.

Distribution: This rare form is found only in the middle part of the Bearpaw Formation from the Castor well.

Remarks: The present form is similar in shape to the Quinqueloculina sp. A figured by Graham and Church (1963) from the Campanian of California, although it is only half the size. Q. sp. A from the Bearpaw sections studied is much narrower and thinner than Q. sphaera Nauss.

Suborder ROTALIINA Delage and Herouard, 1896

Superfamily NODOSARIACEA Ehrenberg, 1838

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus DENTALINA Risso, 1826

DENTALINA BASIPLANATA Cushman

Pl. III, figs. 1, 2.

Dentalina basiplanata Cushman, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 38-39, pl. 6, figs. 6-8; Cushman and Deaderick, 1944, Jour. Paleont., vol. 18, no. 4, p. 333, pl. 51, figs. 17-18; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 68, pl. 24, figs. 1-6; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 174-175, pl. 45, fig. 17; Graham and Church, 1963, Stanford Univ. Pubs. Geol.

Sci., vol. 8, no. 1, p. 27-28, pl. 2, fig. 11; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 18-19, pl. 3, fig. 7.

Description: Test cylindrical, arcuate outline; about six to seven chambers; chambers inflated, early ones low, broad, later ones higher; sutures distinct, flush and slightly oblique at basal end, transverse and depressed toward apertural end; wall smooth, calcareous, finely perforate; aperture terminal, radiate, produced with chamberlet.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 46	1.39	0.25
Hypotype MG 47	1.13	0.35

Location: Hypotype MG 46 is from the Bow City section, JW 66-18, sample 9, 45 feet above the base of the Bearpaw Formation.

Hypotype MG 47 is from the middle part of the Bearpaw Formation, sample B.G. 1, 106-108 feet below the ground level.

Distribution: This species has been reported from the Gulf Coastal region in beds of Taylor and Navarro ages, from the Campanian of California, from the Schrader Bluff Formation of Alaska and from the Lea Park Formation of south-central Saskatchewan.

This species is rare in the sections of the Bearpaw Formation studied. It is present in the basal part of the formation at the Bow City locality, the middle part of the formation near Big Stone and the upper part of the formation from the Castor well.

Remarks: Dentalina basiplanata Cushman is very similar to D. praecommunis Tappan but it lacks the distinctly conical proloculus, has fewer chambers and is much larger.

Superfamily BULIMINACEA Jones, 1875

Family TURRILINIDAE Cushman, 1927

Subfamily TURRILININAE Cushman, 1927

Genus NEOBULIMINA Cushman and Wickenden, 1928

NEOBULIMINA CANADENSIS Cushman and Wickenden

Pl. II, figs. 8, 9.

Neobulimina canadensis Cushman and Wickenden, 1928, Cushman Lab. Foram. Research Contr., vol. 4, p. 13, pl. 1, figs. 1-2; Jennings, 1936, Bull. Am. Paleont., vol. 23, no. 78, p. 31, pl. 3, fig. 22; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 125, pl. 52, figs. 11-12; Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 340, pl. 48, figs. 5 a-b; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 185, pl. 48, figs. 18-27.

Description: Test small, chambers inflated; triserial portion

very small chambers, twisted biserial portion of about four to six chambers of uniform size; chambers becoming globular in biserial portion; sutures distinct, depressed; wall smooth, calcareous, finely perforate; aperture at inner margin on last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 48	0.25	0.13
Hypotype MG 49	0.25	0.11

Location: Hypotypes MG 48 and MG 49 are from the middle part of the Bearpaw Formation, sample Big Stone RG-73.

Distribution: The holotype is from the Bearpaw Formation near Lethbridge, Alberta. According to Cushman (1946) this species is long ranging in the Gulf Coastal region, being found in beds of Austin, Taylor and Navarro ages. It has also been described from the Lea Park Formation of east-central Alberta and the Sentinel Hill and Barrow Trail Members of the Schrader Bluff Formation of Alaska.

This species ranges throughout most of the Bearpaw Formation from the Castor well and is also found in the Bow City section.

Remarks: These hypotypes have fewer chambers in the biserial portion than those figured by Nauss (1947).

The specimens of _N. canadensis_ Cushman and Wickenden from the Bearpaw sections in this study are very small.

Genus PRAEBULIMINA Hofker, 1953

PRAEBULIMINA CARSEYAE (Plummer)

Pl. II, figs. 13, 14.

Buliminella _carseyae_ Plummer. Loetterle, 1937, Nebraska Geol. Surv. Bull. 12, 2nd ser., p. 37, pl. 5, figs. 10 a-b; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 119-120, pl. 50, figs. 17-20.

Praebulimina _carseyae_ (Plummer). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 186, pl. 48, figs. 11-12; _non_ figs. 13-15.

Description: Test small, triserial; four whorls; chambers rapidly increasing in size, last formed whorl very broad, forming at least one-half the length of the test; chambers slightly inflated; sutures distinct, depressed; wall smooth, calcareous, finely perforate; aperture comma-shaped at inner margin of last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Hypotype MG 50	0.20	0.10
Hypotype MG 51	0.22	0.12

Location: Hypotype MG 50 is from the Castor well, 62.2 feet below the top of the Bearpaw Formation.

Hypotype MG 51 is from the Castor well, 166 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from the Upper Cretaceous of Colombia, from the Niobrara Formation of Kansas, Nebraska and South Dakota, from the Gulf Coastal region in beds of Navarro, Taylor and Austin ages and from the Schrader Bluff Formation of Alaska.

This species ranges throughout most of the Bearpaw Formation from the Castor well. It is also found in the Bassano and Big Stone samples.

Remarks: The Bearpaw specimens are smaller than that figured by Loetterle (1937) and are slightly less inflted than <u>Buliminella</u> <u>carseyae</u> Plummer figured by Cushman (1946) from the Navarro marl of Texas.

PRAEBULIMINA sp. cf. P. VENUSAE (Nauss)

Pl. II, fig. 12.

?<u>Bulimina</u> <u>venusae</u> Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334-335, pl. 48, fig. 10.

?<u>Praebulimina</u> <u>venusae</u> (Nauss). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 188, pl. 49, figs. 19-21; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 94, pl. 15, figs. 19-22.

Description: Test slightly elongated; twisted triserial; four to five whorls; basal chambers moderately large; chambers increase markedly in size through last one and one-half whorls; sutures distinct, depressed; wall smooth, calcareous, finely perforate; aperture loop-shaped at inner margin of last formed chamber.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 52	0.27	0.12

Location: Figured specimen MG 52 is from the Castor well, 449 feet below the top of the Bearpaw Formation.

Distribution: Rare individuals of this group are present throughout most of the Bearpaw Formation from the Castor well. The form was also found in the basal part of the formation from the Bow City section.

Remarks: The figured specimen is slightly longer and the last four to five chambers of it are more inflated than those of the holotype of *P. venusae* (Nauss).

Superfamily DISCORBACEA Ehrenberg, 1838

Family DISCORBIDAE Ehrenberg, 1838

Subfamily DISCORBINAE Ehrenberg, 1838

Genus EOEPONIDELLA Wickenden, 1949

EOEPONIDELLA LINKI Wickenden

Pl. II, fig. 15.

Eoeponidella linki Wickenden, 1949, Trans. Roy. Soc. Can., 3rd ser., vol. 42, sec. 4, p. 81-82, figs. 1 a-c; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 195, pl. 54, figs. 9-10.

Description: Test small, low trochospiral, rounded periphery; previous chambers visible on spiral side, only chambers on last whorl and three to four supplementary chambers visible on umbilical side; four slightly inflated chambers in last formed whorl; sutures slightly depressed, distinct, curving; wall smooth, calcareous, perforate; aperture a large high rounded arch on umbilical side of last formed chamber.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 53	0.22	0.20	0.10

Location: Hypotype MG 53 is from the Castor well, 166 feet below the top of the Bearpaw Formation.

Distribution: Wickenden (1949) described the holotype from west-central Saskatchewan in Upper Cretaceous beds apparently equivalent to the upper part of the Lea Park Formation and possibly the Grizzly Bear Shale. The species has been reported from Alaska in the Sentinel Hill Member of the Schrader Bluff Formation.

This species is rare in the Bearpaw Formation sections studied, being found only in the basal part of the formation at Bow City, and the middle part of the formation at Castor.

Remarks: Although many individuals of the genus Eoeponidella Wickenden are present in the Bearpaw sections, only two or three specimens are referable to the species Eoeponidella linki Wickenden.

The figured specimen has fewer chambers in the final whorl, and lacks the definitely stellate arrangement of supplementary chambers found in E. strombodes Tappan.

EOEPONIDELLA STROMBODES Tappan

Pl. II, figs. 16-18.

Eoeponidella strombodes Tappan, 1951, Cushman Found. Foram. Research Contr., vol. 2, pt. 1, p. 6, pl. 1, figs. 22 a-c; Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 195-196, pl. 54, figs. 5-8.

Description: Test medium to small, periphery rounded;

moderately convex on spiral side; seven to nine chambers in final whorl; about two and one-half whorls of previous chambers visible on spiral side; on umbilical side accessory chambers form a stellate pattern of five to seven extra chambers; sutures distinct, slightly depressed, curving, oblique; wall smooth, calcareous, perforate; aperture an arch on the umbilical side of the last formed chamber.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 54	0.20	0.18	0.08
Hypotype MG 55	0.15	0.12	0.05
Hypotype MG 56	0.20	0.15	0.08

Location: Hypotypes MG 54 and MG 55 are from the Castor well, 166 feet below the top of the Bearpaw Formation.

Hypotype MG 56 is from the Castor well, 173 feet below the top of the Bearpaw Formation.

Distribution: This species has only previously been reported from the Sentinel Hill Member of the Schrader Bluff Formation of Alaska.

In the present study this species is quite abundant in the lower two-thirds of the Bearpaw Formation from the Castor well.

Remarks: The Bearpaw specimens are somewhat smaller than those figured by Tappan (1951, 1962) and there are some individuals with apparently only five or six chambers in the final whorl. As the stellate pattern of accessory chambers is very well developed, and the present specimens are otherwise similar to E. strombodes Tappan, they have been included in this species.

Subfamily BAGGININAE Cushman, 1927

Genus VALVULINERIA Cushman, 1926

VALVULINERIA LOETTERLEI (Tappan)

Pl. II, figs.19-21; Pl. III, fig. 3.

Gyroidina loetterlei Tappan, 1940, Jour. Paleont., vol. 14, no. 2, p. 120-121, pl. 19, figs. 10 a-c; Tappan, 1943, Jour. Paleont., vol. 17, no. 5, p. 512, pl. 82, fig. 9. Valvulineria loetterlei (Tappan). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 194-195, pl. 54, figs. 1-4; Eicher, 1965, Jour. Paleont., vol. 39, no. 5, p. 903, pl. 106, figs. 8 a-c.

Description: Test small to medium size, very slightly convex on spiral side; umbilical side deep; about six to seven chambers in final whorl; previous chambers not clearly visible on spiral side; chambers slightly inflated; sutures slightly depressed between later chambers, curved slightly on umbilical side, curved, oblique on spiral side; wall

smooth, calcareous, finely perforate; aperture a slit at base of terminal face, bordered by a lip which extends as an umbilical flap.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 57	0.27	0.22	0.15
Unfigured hypotype MG 58	0.20	0.18	0.12
Hypotype MG 59	0.32	0.22	0.20
Hypotype MG 60	0.47	0.37	0.25
Hypotype MG 61	0.25	0.22	0.12

Location: Hypotype MG 57 is from the Castor well, 77.5 feet below the top of the Bearpaw Formation.

Unfigured hypotype MG 58 is from the Castor well, 445.5 feet below the top of the Bearpaw Formation.

Hypotype MG 59 is from the middle part of the Bearpaw Formation, sample B.G. 1, 106-108 feet below the ground level.

Hypotypes MG 60 and MG 61 are from the Bow City section, JW 66-18, sample 8, 32 feet above the base of the Bearpaw Formation.

Distribution: This species has been reported from the Albian Washita Group of Texas and Oklahoma and the Albian Grandstand and Topagoruk Formations of Alaska.

This species is moderately abundant throughout most of the Bearpaw Formation from the Castor well and is also present in the Bow City, Bassano, Dorothy and Big Stone sections.

Remarks: At least the final chamber appears to be broken off in most of the present material. Many specimens from the Bow City locality are larger than those figured by Tappan (1940, 1943, 1962) and Eicher (1965). These specimens are well preserved and the umbilical flap is very well developed.

?VALVULINERIA sp. A

Pl. III, figs. 13, 15.

Description: Test small to medium size, rounded periphery, unequally convex; small umbilicus developed; eight to nine chambers in final whorl, previous chambers visible on spiral side, only chambers of final whorl visible on umbilical side; sutures not depressed, distinct, limbate, slightly curved to straight on spiral side, curved on umbilical side; wall calcareous, coarsely perforate; frequently surface covering of white cement with black ornamentation; aperture at base of terminal chamber extending to umbilicus, bordered by a small lip.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Figured specimen MG 73	0.27	0.22	0.12
Figured specimen MG 74	0.25	0.20	0.12

Location: Figured specimen MG 73 is from the Castor well, 365 feet below the top of the Bearpaw Formation.

Figured specimen MG 74 is from the middle Bearpaw Formation, sample B.G. 1, 106-108 feet below the ground level.

Distribution: This form is rare, being found only in the basal part of the Bearpaw Formation from the Castor well, and from an isolated core sample taken near the town of Big Stone.

Remarks: The covering of white cement is not present on all individuals of this group, but when it is present it badly obscures the morphologic details.

This form may well represent a new genus, but it has been designated as ?Valvulineria sp. A for the purposes of this thesis.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family HETEROHELICIDAE Cushman, 1927

Subfamily HETEROHELICINAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1843

HETEROHELIX GLOBULOSA (Ehrenberg)

Pl. II, fig. 22.

Gumbelina globulosa (Ehrenberg). Jennings, 1936, Bull. Am. Paleont., vol. 23, no. 78, p. 27, pl. 3, fig. 9; Loetterle, 1937, Nebraska Geol. Surv. Bull. 12, 2nd ser., p. 33, pl. 4, figs. 8 a-b; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 105-106, pl. 45, figs. 9-15; Young, 1951, Jour. Paleont., vol. 25, no. 1, p. 63, pl. 14, figs. 12, 24-25; non figs. 23, 26; Stelck and Wall, 1954, Res. Coun. Alberta Rept. 68, p. 22, pl. 2, figs. 20 a-b; Bolin, 1956, Jour. Paleont., vol. 30, no. 2, p. 289-290, pl. 38, figs. 10-11, 14, 16.

Heterohelix globulosa (Ehrenberg). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 196, pl. 55, figs. 1-2; Graham and Church, 1963, Stanford Univ. Pubs. Geol. Sci., vol. 8, no. 1, p. 61-62, pl. 7, figs. 11 a-c; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 21, pl. 3, figs. 11 a-b; Eicher, 1965, Jour. Paleont., vol. 39, no. 5, p. 904, pl. 106, figs. 3 a-b; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 102-103, pl. 3, figs. 26-27.

Description: Test small, expands rapidly from small-chambered basal portion, about six pairs of oblique chambers, slightly inflated; sutures depressed, distinct; wall smooth, calcareous, finely perforate; aperture on inner margin of terminal face.

Dimensions:	Length (mm.)	Width (mm.)	Thickness (mm.)
Hypotype MG 62	0.20	0.12	0.08

Location: Hypotype MG 62 is from the Castor well, 62.2 feet below the top of the Bearpaw Formation.

Distribution: This species has been described from the Upper Cretaceous of Cuba and Colombia, the Campanian of California, the Niobrara Formation of Kansas, Nebraska and South Dakota, and from beds of Upper Navarro to Middle Taylor ages in the Gulf Coastal region. In western Canada the species has been reported from the Kaskapau Formation of northern Alberta, the Blackstone and Wapiabi Formations of the Foothills and the Lea Park Formation of south-central Saskatchewan. In Alaska the species is reported to be somewhat rare, and is restricted to the Seabee Formation of Turonian age.

This species is restricted to a thin band in the upper part of the Bearpaw Formation from the Castor well and the Bassano outcrop section.

Remarks: Heterohelix globulosa (Ehrenberg) and Globigerinelloides aspera (Ehrenberg) are the only planktonic foraminifers recovered from the Bearpaw Formation in this study.

Family PLANOMALINIDAE Bolli, Loeblich and Tappan, 1957

Genus GLOBIGERINELLOIDES Cushman and Ten Dam, 1948

GLOBIGERINELLOIDES ASPERA (Ehrenberg)

Pl. III, figs. 4, 6.

Globigerinella aspera (Ehrenberg). Jennings, 1936, Bull. Am. Paleont., vol. 23, no. 78, p. 36, pl. 4, fig. 11; Loetterle, 1937, Nebraska Geol. Surv. Bull. 12, 2nd ser., p. 45-46, pl. 7, figs. 4 a-b; Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 337, pl. 48, fig. 9; Bandy, 1951, Jour. Paleont., vol. 25, no. 4, p. 508, pl. 75, figs. 3 a-c; Bolin, 1956, Jour. Paleont., vol. 30, no. 2, p. 294, pl. 39, figs. 9-11.

"Globigerinella" aspera (Ehrenberg). Graham and Church, 1963, Stanford Univ. Pubs. Geol. Sci., vol. 8, no. 1, p. 64-65, pl. 7, figs. 17 a-c.

Globigerina aspera (Ehrenberg). Wall, 1960, Res. Coun. Alberta Bull. 6, p. 32, pl. 5, figs. 13-14; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 25, pl. 4, figs. 8 a-b.

Description: Test medium to small size, planispiral, biumbilicate; chambers increasing rapidly in size, inflated, six to seven in final whorl; sutures distinct, slightly

curved, depressed; wall hispid, calcareous, finely perforate; aperture equatorial arch with narrow lip developed.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 63	0.27	0.20	0.12
Hypotype MG 64	0.15	0.10	0.05

Location: Hypotype MG 63 is from the Dorothy section, MG 68-3, sample 5, 72 feet below the top of the Bearpaw Formation.

Hypotype MG 64 is from the Bassano South section, JW 66-17, sample 7, 61 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from the Niobrara Formation of Kansas, Nebraska and South Dakota, the Campanian of California, the Kaskapau and Puskwaskau Formations of the Smoky River area, Alberta and the Lea Park Formation of east-central Alberta and west-central Saskatchewan.

In the Bearpaw Formation this species is restricted to a narrow interval in the upper part of the formation at the Dorothy and Bassano South localities.

Remarks: There is the suggestion of two relict apertures opening into the umbilical region of hypotype 63. These relict apertures diagnostic of the genus <u>Globigerinelloides</u>

are apparently lacking on specimens figured by other authors.

The specimens figured by Loetterle (1937), Nauss (1947) and Wall (1960) are larger than the Bearpaw specimens. "Globigerinella" aspera (Ehrenberg) figured by Graham and Church (1963) from the Campanian of California appears very similar to the Bearpaw forms.

Superfamily CASSIDULINACEA d'Orbigny, 1839

Family CAUCASINIDAE N.K. Bykova, 1959

Subfamily FURSENKOININAE Loeblich and Tappan, 1961

Genus CASSIDELLA Hofker, 1951

?CASSIDELLA sp. A

Pl. III, fig. 10.

Description: Test elongated, early stage small chambered, apparently triserial, later portion has seven pairs of chambers; chambers oblique to long axis of test; sutures distinct, slightly depressed; wall smooth, calcareous, finely perforate; aperture a slit on inner margin.

Dimensions:	Length (mm.)	Width (mm.)
Figured specimen MG 65	0.25	0.08

Location: Figured specimen MG 65 is from the Bassano South section, JW 66-17, sample 7, 61 feet below the top of the Bearpaw Formation.

Distribution: The form occurs in the upper part of the Bearpaw Formation from the Castor well, and the outcrop localities of Bassano and Dorothy. It is also present in the upper middle part of the formation near the town of Big Stone.

Remarks: These specimens are provisionally assigned to the genus Cassidella Hofker as a toothplate has not definitely been seen.

Family NONIONIDAE Schultze, 1854

Subfamily NONIONINAE Schultze, 1854

Genus NONIONELLA Cushman, 1926

NONIONELLA TAYLORENSIS Hofker

Pl. III, figs. 11, 14.

Nonionella cretacea Cushman. Jennings, 1936, Bull. Am. Paleont., vol. 23, no. 78, p. 25, pl. 3, figs. 3 a-b; Cushman, 1946, U.S. Geol. Surv. Prof. Paper 206, p. 101, pl. 43, figs. 24 a-c.

Nonionella taylorensis Hofker. Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 190, pl. 50, figs. 10-12.

Description: Test small, asymmetrically coiled, periphery rounded; seven chambers in final whorl; on one side inner margin of last chamber overlaps previous chambers tending to obscure them; sutures distinct, slightly depressed,

curved; wall smooth, calcareous, finely perforate; aperture interiomarginal extending into the umbilical area.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 66	0.20	0.12	0.08
Hypotype MG 67	0.18	0.12	0.08

Location: Hypotype MG 66 is from the Castor well, 257 feet below the top of the Bearpaw Formation.

Hypotype MG 67 is from the Dorothy locality, MG 68-3, sample 5, 72 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from the Gulf Coastal region in beds of Navarro and Taylor ages, and in the Upper Cretaceous of Mexico. In Alaska, the species is apparently limited to the Schrader Bluff Formation.

This species is very rare in the Bearpaw Formation with only a few specimens collected from the lower half of the formation from the Castor well, and from an interval in the upper part of the formation at Bassano and Dorothy.

Remarks: The specimen described by Tappan (1962) has eight to ten chambers in the final whorl, but the specimens figured by her appear to have only six to seven chambers in the final whorl. The Bearpaw specimens resemble the latter.

The figured specimens are slightly smaller than those figured by Jennings (1936) and Cushman (1946).

Family ANOMALINIDAE Cushman, 1927

Subfamily ANOMALININAE Cushman, 1927

Genus ANOMALINOIDES Brotzen, 1942

ANOMALINOIDES PINGUIS (Jennings)

Pl. III, fig. 5.

Anomalina pinguis Jennings, 1936, Bull. Am. Paleont., vol. 23, no. 78, p. 37-38, pl. 5, fig. 1.

Description: Test medium size, planispiral, umbilicus developed; seven to nine chambers in final whorl, chambers moderately inflated; previous chambers not visible on umbilical side, last whorl overlaps previous chambers somewhat on spiral side; sutures distinct, limbate, curved slightly, ultimate and penultimate depressed, others flush; wall smooth, calcareous, coarsely perforate; aperture a slit at base of terminal face extending along spiral suture for 2 or 3 chambers, bordered by a lip.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 68	0.68	0.32	0.20

Location: Hypotype MG 68 is from the middle part of the Bearpaw Formation, sample B.G. 1, 106-108 feet below ground

level.

Distribution: This species was recovered only from the single sample B.G. 1 from the lower middle part of the Bearpaw Formation, 106-108 feet below the ground level near the town of Big Stone.

Remarks: The figured specimen is larger than the holotype.

ANOMALINOIDES TALARIA (Nauss)

Pl. III, figs. 7-9, 12.

Anomalina talaria Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 334, pl. 48, figs. 11-12.

Anomalinoides talaria (Nauss). Tappan, 1962, U.S. Geol. Surv. Prof. Paper 236-C, p. 200, pl. 58, figs. 6-10; North and Caldwell, 1964, Saskatchewan Res. Coun. Rept. 5, p. 24, pl. 4, figs. 10 a-c; Wall, 1967, Res. Coun. Alberta Bull. 20, p. 112-113, pl. 6, figs. 10-15; pl. 9, figs. 25-27; pl. 15, figs. 7-12.

Description: Test small, round, trochoid, slightly depressed on spiral side; eight or nine chambers in final whorl; previous chambers partially visible on spiral side; nearly involute on umbilical side; umbilicus dark, round, slightly depressed; wall smooth, calcareous, finely perforate; aperture an arched slit on periphery extending back

along spiral suture for a short distance, may extend along chamber margins on umbilical side for four or five chambers, aperture may be bounded by an irregular flange on umbilical side.

Dimensions:	Max. diam. (mm.)	Min. diam. (mm.)	Thickness (mm.)
Hypotype MG 69	0.20	0.15	0.08
Hypotype MG 70	0.15	0.12	0.05
Hypotype MG 71	0.20	0.15	0.08
Hypotype MG 72	0.22	0.18	0.10

Location: Hypotypes MG 69 and MG 70 are from the Castor well, 81 feet below the top of the Bearpaw Formation.

Hypotype MG 71 is from the Castor well, 195 feet below the top of the Bearpaw Formation.

Hypotype MG 72 is from the Castor well, 405.5 feet below the top of the Bearpaw Formation.

Distribution: The holotype is from the Lea Park Formation of east-central Alberta and the species has been reported from the upper Lea Park Formation of Saskatchewan, the Wapiabi Formation of the Alberta Foothills and the Schrader Bluff Formation of Alaska.

The species is quite abundant in the Bearpaw Formation and was present throughout most of the formation from the Castor well. It also occurs at the outcrop localities of Dorothy and Bow City, and in the isolated core samples from near the town of Big Stone.

Remarks: Dextral and sinistral forms appear to be about equally common in the Bearpaw Formation samples, with perhaps a slight preponderance of sinistral forms.

The Bearpaw specimens are somewhat smaller than Anomalinoides talaria (Nauss) from the Lea Park Formation.

Subclass RADIOLARIA Muller, 1858

Order PORULOSIDA Haeckel, 1887

Suborder SPUMELLINA Ehrenberg, 1875

Division SPHAERELLARI Haeckel, 1882

Superfamily ELLIPSIDIICAE Haeckel, 1887

Family SPONGURIIDAE Haeckel, 1862

Subfamily SPONGURINAE Haeckel, 1862

Genus SPONGOPRUNUM Haeckel, 1887

?SPONGOPRUNUM sp. A

Pl. III, fig. 22.

Description: A 0.20 by 0.20 mm. pyritized cylindrical body with two opposite polar spines. The overall length is 0.35 mm.

Location: Figured specimen MG 80 is from the Castor well, 379 feet below the top of the Bearpaw Formation.

Distribution: This form is very rare in the Bearpaw Formation, being found only in the upper part of the formation from the Castor well and the basal part of the formation from the Bow City section.

Remarks: This form is provisionally assigned to the genus Spongoprunum Haeckel as the external or medullary shell structure could not be determined.

?SPONGOPRUNUM sp. B

Pl. III, fig. 21.

Description: A 0.25 by 0.18 mm. pyritized cylindrical body with two opposite polar spines. The overall length is 0.27 mm.

Location: Figured specimen MG 81 is from the Castor well, 435 feet below the top of the Bearpaw Formation.

Distribution: This is a rare form in the Bearpaw Formation. It is found in the upper part of the formation from the Castor well and the basal part of the formation at the Bow City locality.

Remarks: ?*Spongoprunum* sp. B differs from ?*S*. sp. A as it has a cylindrical body which is somewhat longer and much thinner.

Superfamily CENODISCICAE Haeckel, 1887

Subsuperfamily EUCHITONIILAE Haeckel, 1887

Family SPONGODISCIDAE Haeckel, 1882

Subfamily SPONGODISCINAE Haeckel, 1882

Genus SPONGODISCUS Ehrenberg, 1845

?SPONGODISCUS sp.

Pl. III, fig. 20.

Description: A 0.10-0.20 mm. diameter round, pyritized

disc with no apparent external morphology.

Location: Figured specimen MG 77 is from the Castor well, 22 feet below the top of the Bearpaw Formation.

Distribution: This form is moderately abundant in the Bearpaw Formation throughout the Castor well, and is also present in the basal part of the formation at the Bow City locality.

Remarks: Several individuals of this group appear to show incipient or broken spines around the periphery of the body. These individuals might more properly be assigned to either <u>Spongostaurus</u> or <u>Stylospongia</u>.

Subfamily SPONGOTROCHINAE Haeckel, 1882

Genus SPONGOTROCHUS Haeckel, 1860

?SPONGOTROCHUS sp.

Pl. III, fig. 17.

Description: A 0.12 mm. diameter round, pyritized disc with a central circular depression and ten spines or spokes radiating outward to the periphery from this depression.

Location: Figured specimen MG 79 is from the Castor well, 250 feet below the top of the Bearpaw Formation.

Distribution: This form is found in the upper half of the

Bearpaw Formation from the Castor well, and is also present from the Bassano and Bow City localities.

Subfamily SPONGOBRACHIINAE Haeckel, 1882

Genus SPONGASTER Ehrenberg, 1860

?SPONGASTER sp.

Pl. III, fig. 19.

Description: A 0.2 mm. diameter pyritized disc with a cross-shaped depression in the central portion.

Location: Figured specimen MG 76 is from the Castor well, 22 feet below the top of the Bearpaw Formation.

Distribution: This form is restricted to two occurrences in the lower 25 feet of the Bearpaw Formation from the Castor well.

Order OCULOSIDA Haeckel, 1887

Suborder NASSELLINA Ehrenberg, 1875

Division CYRTELLARI Haeckel, 1882

Superfamily ARCHIPILIICAE Haeckel, 1882

Subsuperfamily TRIACARTILAE Campbell, 1954

Family STICHOCORYTHIDAE Haeckel, 1882

Subfamily STICHOCORYTHINAE Haeckel, 1882

Genus DICTYOMITRA Haeckel, 1887

DICTYOMITRA MULTICOSTATA Zittel, 1876

Pl. III, fig. 16.

Dictyomitra multicostata Zittel. Nauss, 1947, Jour. Paleont., vol. 21, no. 4, p. 341, pl. 48, fig. 3.

Description: Body somewhat conical, consisting of about six joints which have longitudinal striations and which gradually increase in length and breadth.

Dimensions:	Length (mm.)	Max. Width (mm.)
Hypotype MG 75	0.25	0.12

Location: Hypotype MG 75 is from the Castor well, 257 feet below the top of the Bearpaw Formation.

Distribution: This species has been reported from the Lea Park Formation and Lloydminster Shale of east-central Alberta, the Upper Cretaceous of California, and the upper

part of the Schrader Bluff Formation of Alaska.

The species is very rare in the Bearpaw Formation, occurring in the lower part of the formation from the Castor well and in the lower middle part of the formation from the core taken near Big Stone.

Remarks: The specimen is incomplete and pyritized.

INCERTAE SEDIS sp. A

Pl. III, fig. 18.

Description: A 0.12 mm. diameter pyritized round disc with three raised symmetrical triangular wedges radiating out from the center of the disc.

Location: Figured specimen MG 78 is from the Castor well, 22 feet below the top of the Bearpaw Formation.

Distribution: This form is restricted to sporadic occurrences in the basal part of the Bearpaw Formation at the Bow City locality and the upper part of the formation from the Castor well.

Remarks: This specimen may be a radiolarian of the genus Triopyle Haeckel, with the gates being completely filled in by pyrite.

INCERTAE SEDIS sp. B

Pl. III, figs. 23, 24.

Description: A 0.25-0.27 mm. diameter brown sphere with no visible external morphology or aperture; surface may be slightly roughened.

Location: Figured specimen MG 82 is from the Castor well,

354 feet below the top of the Bearpaw Formation.

Figured specimen MG 84 is from the Castor well, 29.5 feet below the top of the Bearpaw Formation.

Distribution: This form is present sporadically throughout the Bearpaw Formation from the Castor well. It is also present in the core from Big Stone and the outcrop localities of Bow City, Bassano and Dorothy.

INCERTAE SEDIS sp. C

Pl. III, fig. 27.

Description: A 0.10 mm. diameter, round to slightly ovoid smooth-walled pale tan colored sphere with no visible aperture or external morphology.

Location: Figured specimen MG 83 is from the Castor well, 21.5 feet below the top of the Bearpaw Formation.

Distribution: This form is present sporadically throughout the Bearpaw Formation from the Castor well, and is also present at the Bow City locality.

INCERTAE SEDIS sp. D

Pl. III, fig. 26.

Description: A 0.18 mm. diameter round, dark brown sphere

with a suggestion of a round aperture.

Location: Figured specimen MG 85 is from the Castor well, 35.5 feet below the top of the Bearpaw Formation.

Distribution: This form is present sporadically in the lower part of the Bearpaw Formation from the Castor well and Bow City locality, and the upper part of the formation from the Castor well, Bassano and Dorothy localities.

Remarks: This form is very similar to incertae sedis sp. C. It differs in being larger and of a much darker color with the slight suggestion of an aperture noted.

INCERTAE SEDIS sp. E

Pl. III, fig. 28.

Description: A 0.12 by 0.10 mm. oval sphere, dark amber brown in color; elongated to slight neck with terminal round aperture.

Location: Figured specimen MG 86 is from the Castor well, 42 feet below the top of the Bearpaw Formation.

Distribution: This form is present sporadically throughout most of the Bearpaw Formation from the Castor well and is also found at the Dorothy and Big Stone localities.

Remarks: This form is very similar to incertae sedis sp. D but is slightly smaller and has a definite aperture formed.

INCERTAE SEDIS sp. F

Pl. III, fig. 25.

Description: A 0.20 by 0.15 mm. oval sphere, white, smooth-walled; very slightly pointed toward one end; no aperture visible.

Location: Figured specimen MG 87 is from the Castor well, 81 feet below the top of the Bearpaw Formation.

Distribution: This form is present sporadically throughout most of the Bearpaw Formation from the Castor well, and is also present at the Bow City and Dorothy localities.

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APPENDIX

SAMPLE LOCALITIES AND DESCRIPTIONS

A. Subsurface Samples

1. Research Council Castor - complete core.
Lsd 13-34-37-13W4.
Elevation: Ground level 2600 feet above sea level.
All sample weights 150 grams unless otherwise noted.

Core No.	Interval	Recovery	Lithology	Sample No.
21	94.6-101.6	full+	5'0" Sandstone - dark grey, bentonitic, argillaceous, laminated	
			EDMONTON - BEARPAW CONTACT 98'	
			3'0" Shale - brownish-grey and dark grey, fairly soft, quite bentonitic in part, laminated	1
22	101.6-108.6	full	Shale - dark grey to black, rather soft, bentonitic, slightly silty in places (laminae)	2, 3
23	108.6-116.0	6'2"	Shale - dark grey to medium grey, bentonitic in upper foot, somewhat silty below (laminae), possible worm burrows in upper part	4, 5
24	116-123	full	Shale - medium to dark grey, bentonitic in part, some silty laminae, carbonaceous material	6, 7
25	123-130	6'0"	Shale - medium to dark grey, some silty laminae, pyrite stringers, a few bentonitic beds, carbonaceous material	8, 9
26	130-137	full	Shale - similar to above, bentonitic beds more prominent	10, 11

Core No.	Interval	Recovery	Lithology	Sample No.
27	137-143	full	Shale - medium grey, essentially similar to above	12, 13
28	143-150	full	Shale - medium to dark grey, less silty, bentonitic in part, shell fragments in lower portion, carbonaceous material, more marine appearance than above	14. 15
29	150-157	6'5"	Shale - dark grey, similar to above, shell fragments, pyrite stringers	16, 17
30	157-164	6'7"	Shale - medium grey, some fairly sandy beds, silty, occasionally bentonitic, carbonaceous fragments	18, 19
31	164-172	7'3"	Shale - medium to dark grey, bentonitic in part, rare carbonaceous flecks, little silt	20, 21
32	172-179	full	Shale - steel grey, occasionally bentonitic, little silt, shell fragments, carbonaceous material	22, 23
33	179-186	full+	2'8" Shale - medium to dark grey, bentonitic, especially in lower foot, glauconitic	24
			<u>"FIRST CASTOR SANDSTONE" 182'</u>	
			5'4" Sandstone - greyish-green, medium to coarse grained, glauconitic, especially in upper foot, kaolinitic cement, non-calcareous, buff clay beds in upper foot	
34	186-193	4'9"	Sandstone - greyish-green, and grey, moderately glauconitic in part, somewhat soft and laminated, a few beds of fair porosity, a few bentonitic laminae and carbonaceous stringers	

Core No.	Interval	Recovery	Lithology	Sample No.
35	193-200	6'0"	Sandstone - grey and greyish-green, similar to above, bentonitic laminae more prominent, intermittent carbonaceous lenses	
36	200-208	7'3"	Sandstone - grey, medium grained, kaolinitic cement, bentonitic laminae common, one buff clay band near top	
37	208-215	6'6"	Sandstone - grey to greyish-green, medium grained, bentonitic laminae more prevalent in upper 2 feet	
38	215-222	5'7"	Sandstone - grey to greyish-green, medium grained, kaolinitic cement, some bentonitic laminae, rare carbonaceous lenses	
39	222-229	full	Sandstone - similar color, grain, habit, calcareous in upper 3 feet, remainder has much bentonitic material, rare carbonaceous laminae	
40	229-236	7'0"	Sandstone - grey to greyish-green, medium grained, non-calcareous, bentonitic laminae fairly common	
41	236-243	6'7"	5'0" Sandstone - grey, medium grained, carbonaceous band near top 1'7" Siltstone - sombre grey, bentonitic shaley laminae <u>BASE "FIRST CASTOR SANDSTONE" 241'</u>	
42	243-250	full	Siltstone and shale - light to dark grey, interbanded, sporadic beds of bentonitic material, thin bands of buff clayey material, carbonaceous	25, 26

Core No.	Interval	Recovery	Lithology	Sample No.
43	250-257	6'8"	Shale - dark grey, waxy luster, bentonitic in part, some bands of light grey siltstone and occasional thin buff clay, carbonaceous material, shell fragments	27, 28
44	257-264	full	Shale - similar to above, siltstone bands	29, 30
45	264-271	full	Shale - dark grey, some shell fragments, flecks of carbonaceous material, a few siltstone bands in top of core	31, 32
46	271-279	full	3'6" Shale - dark grey, similar to above 4'6" Siltstone - light to medium grey, lenses and laminae of shale	33 34
47	279-286	6'6"	4'6" Siltstone - as above 2'0" Shale - dark grey, conchoidal fracture, shell fragments, bentonitic, carbonaceous material	35, 36
48	286-293	full	Shale - dark grey, silty lenses, shell fragments, 3 inch band of greenish bentonite 2 feet from bottom, pyrite stringers, carbonaceous material	37, 38
49	293-300	full	Shale - medium to dark grey, some silty lenses, bentonitic laminae, shell fragments, some pyrite stringers, carbonaceous material	39, 40
50	300-307	full	Siltstone - argillaceous and shaley, silty lenses, pyrite stringers, shell fragments	41, 42
51	307-314	full	Siltstone and shale - as above, carbonaceous material, sand at bottom, core stuck in barrel and was badly mudded "SECOND CASTOR SANDSTONE" 314'	43, 44

Core No.	Interval	Recovery	Lithology	Sample No.
52	314-321	4'2"	Sandstone - greyish-green, medium grained, glauconitic, kaolinitic cement, non-calcareous, quite compact but porosity appears fair in places, sporadic buff clayey inclusions	
53	321-328	5'6"	Sandstone - as above, lower foot is calcareous, has bentonitic laminae	
54	328-335	6'6"	Sandstone - calcareous in upper 6 inches, glauconitic in part, medium grained, some buff clayey inclusions	
55	335-342	6'0"	Sandstone - greyish-green, medium grained, non-calcareous, glauconitic, kaolinitic cement, somewhat bentonitic or argillaceous in lower part	
56	342-348	full	5'6" Sandstone - similar to above 0'6" Shale - dark grey, bentonitic	
			BASE "SECOND CASTOR SANDSTONE" 348'	
57	348-355	full	Shale - dark grey, waxy luster, bentonitic, somewhat silty, intermittent sand lenses, pelecypods, pyrite stringers	45, 46
58	355-362	5'6"	Shale - dark grey, quite bentonitic in places, some sand, silty, several 1/2 to 1 inch bands of buff clay ironstone, carbonaceous material, shell fragments	47
59	362-369	6'0"	Shale - medium to dark grey, sandy with many lenses, thin bands of glauconitic sand, a few carbonaceous lenses, pyrite stringers, shell fragments	48

Core No.	Interval	Recovery	Lithology	Sample No.
60	369-377	full+	2'6" Shale - mostly dark grey, bentonitic, little silt, pyrite stringers 3'0" Shale - much sand, 2 inch hard calcareous conretionary band 1 foot from top of this section 3'6" Shale - medium to dark grey, bentonitic in part, similar to top of core, some silty laminae	49, 50
61	377-385	full	Shale - medium to dark grey, bentonitic in part, some laminae or thin bands of silt or fine sand, shell fragments, carbonaceous material	51, 52
62	385-393	full	Shale - dark grey, partly bentonitic, some silty lenses, sandstone in bands up to 2 inches thick, green, glauconitic, medium grained, some thin bands of buff clayey material, shell fragments	53, 54
63	393-400	6'0"	Sandstone - green, medium grained, bentonitic, particularly lower portion Shale - dark grey, partly bentonitic, some silty laminae, a few buff clayey inclusions, an indurated band 3 feet from top of core	55
64	400-407	full+	Shale - dark grey, bentonitic, lenses of green, medium grained sand, some carbonaceous material	56, 57
65	407-414	5'0"	3'0" Shale - dark grey, lenses of grey silt and green sand 2'0" Sandstone - green, glauconitic, sporadic shale or buff clay bands, the latter indurated in part	58

Core No.	Interval	Recovery	Lithology	Sample No.
66	414-421	6'0"	2'6" Sandstone - green, similar to above, bentonitic in part, also shale and clay bands 3'6" Shale - dark grey, bentonitic, silty, carbonaceous material	59
67	421-428	full	Shale - dark grey, bentonitic in part, laminae and bands of silt, fine-grained sand, carbonaceous material	60, 61
68	428-434	full	Sandstone - green, medium grained, bentonitic, 1 inch band of dark shale near top of core, 3 inch band of buff indurated clay ironstone 2 feet from top	62 (100 grams)
69	434-441	full+	1'0" Sandstone- greenish-grey, fine-grained, compact, irregular interbeds of dark bentonitic shale 7'6" Shale and sandstone - closely associated in bands and lenses, bentonitic, shale predominates in upper part of core, sandstone in lower part	
70	441-448	full	Sandstone - greenish-grey, fine to medium grained, non-calcareous, keolinitic cement, some bentonitic laminae, shell fragments	
71	448-452	3'4"	Siltstone - light grey, closely associated with bands and cross-beds of dark grey shale, bentonitic in part	
72	452-457	full+	Shale - dark grey, bands and lenses of silt common in upper foot, rare to absent below, some shell fragments	63
73	457-463	full+	Shale - medium grey, mostly in buttons, a few silty lenses, lenses of medium grained, green glauconitic	64, 65

Core No.	Interval	Recovery	Lithology	Sample No.
			sand in lower 3 to 4 feet, large shell fragments in lower part	
74	463-470	full+	Shale - medium grey, mostly in buttons except for massive material in upper foot (core very muddy), some silty lenses and pyrite stringers, shell fragments, brownish bentonitic material in lower foot	66, 67
75	470-477	full	Shale - medium grey, with lenses, bands of green, fine to medium grained glauconitic sand, a few bentonitic laminae, shell fragments, carbonaceous material, probable worm burrows	68
76	477-484	full+	3'0" Sandstone - greenish-grey, fine grained, argillaceous, large shells 5'0" Shale - medium to dark grey, conchoidal fracture, sand lenses in upper part, becoming cleaner with depth, some bentonitic lenses	69, 70
77	484-491	full	Shale - medium to dark grey, largely in buttons, some more massive, little silt, shell fragments, 4 inch band of greenish bentonite 2 to 3 feet from bottom of core, carbonaceous fragments	71, 72
78	491-498	full+	Shale - medium to dark grey, conchoidal fracture, not silty, bentonitic in places, shell fragments, pyrite stringers	73, 74
79	498-505	full+	Shale - medium to dark grey, conchoidal fracture, sandy in upper 2 feet and lower 1 foot, lenses of greenish sand, some shell fragments, pyrite stringers	75, 76

Core No.	Interval	Recovery	Lithology	Sample No.
80	505-512	full+	Shale - medium to dark grey, sand lenses, bentonitic laminae, basal foot particularly sandy and bentonitic, 2 feet from bottom a 3 to 4 inch buff, hard concretionary calcareous band, carbonaceous material	77, 78
81	512-519	full+	Shale - similar to lower foot of above core, rare buff claystone patches, shell fragments, carbonaceous material	79, 80
82	519-526	full+	Shale - generally less sandy than above, bentonitic in places, shale fragments, carbonaceous material	81, 82
83	526-533	full+	1'6" Shale - medium grey, slightly to moderately sandy, shell fragments, carbonaceous material 5'6" Shale - dark grey, mostly in buttons, very bentonitic, some lenses of silt, sand, core was exceptionally sticky	83, 84
84	533-540	full+	Shale - dark grey, massive conchoidal fracture, some bentonitic layers, lenses or worm burrows of silt to fine grained sand, shell fragments, carbonaceous material	85, 86
85	540-547	full	Shale - dark grey, blocky, massive, hard, lenses and stringers of silt to sand fairly common, pyrite stringers	87, 88
86	547-554	full+	Shale - dark grey, mostly laminated, conchoidal fracture, some sandy lenses, bentonitic layer, relatively silt-free	89, 90

Core No.	Interval	Recovery	Lithology	Sample No.
87	554-561	full+	Shale - medium to dark grey, blocky-massive to fissile, lenses of fine grained sand, laminae of light grey silt, some bentonitic patches, bands of buff clayey material, shell fragments, worm burrows	91
88	561-568	full	Shale - medium to dark grey, in buttons, some silt laminae, plant remains common, beginning a foot below top, some bentonitic layers in middle of core	92 93 (135 grams)
			BEARPAW - BELLY RIVER CONTACT 568'	
89	568-575	full+	4'0" Shale - dark greyish-brown to black, fissile, carbonaceous with bands of coal 3'0" Shale - dusky yellow, bentonitic with sporadic carbonaceous fragments	

2. B.G. 67-3-18 (Big Stone) - shothole cuttings.
   Lsd 4-15-26-8W4.
   Elevation 2775 feet above sea level.
   Sample weight 200 grams.

   Shale and silt - intermixed, disseminated pyrite.

3. B.G. 1 (Big Stone) - partial core.
   Lsd 4 -22-26-8W4.
   Elevation 2770 feet above sea level.
   Sample weights 150 grams.

Sample No.	Interval	Lithology
1	106-108	Shale - medium brown-grey, silty with some silt laminae, sandy lenses, bentonitic, pyrite stringers, rusty weathering, shell fragments
2	157-159	Shale - medium brown grey, silty, pyrite stringers, carbonaceous material, lower foot is fine grained, rather platy or laminar, soft, upper foot is coarse-grained, siltier, very hard, blocky, rather than laminar

B. Outcrop Samples

1. Bow City: JW 66-18.
SW 17-17-17W4.
Elevation at base of section 2500 feet above sea level.
All sample weights 150 grams.

Sample No.	Interval	Lithology	Total Section
	0'2"	Bentonite - yellow	0' 2"
	6'0"	Shale - medium grey, some silt, little weathering, shell fragments	6' 2"
	3'0"	Shale - similar to above, somewhat bentonitic, ironstone concretion band	9' 2"
18	7'0"	Shale - medium grey, some silt, little weathering, shell fragments	16' 2"
	0'2"	Bentonite - blue grey to yellow	16' 4"
	1'0"	Shale - similar to above	17' 4"
17	9'0"	Shale - similar to above	26' 4"
16	9'0"	Shale - similar to above	35' 4"
15	8'6"	Shale - medium brown grey, silty, disseminated pyrite, rusty weathering, somewhat blocky, carbonaceous fragments, ironstone concretions present in upper foot	43'10"
14	7'0"	Shale - similar to above	50'10"
13	6'0"	Shale - medium grey, some silt, rusty weathering, more blocky, shell fragments, some ironstone concretions up to 9 inches high present in upper 1 foot	56'10"
12	6'0"	Shale - medium brown grey, silty, pyrite stringers, rusty weathering, blocky, carbonaceous material	62'10"
11	6'0"	Shale - similar to above	68'10"

Sample No.	Interval	Lithology	Total Section
10	5'0"	Shale - similar to above, slightly bentonitic	73'10"
9	5'0"	Shale - medium grey, some silt, rusty weathering, more blocky, shell fragments	78'10"
		Section moved 1/3 to 1/2 mile upstream.	
	0'2"	Bentonite - bluish-grey	79' 0"
8	8'0"	Shale - medium grey, some silt, more friable, less weathered, somewhat bentonitic	87' 0"
7	7'6"	Shale - dark blue grey, less friable, some silt, some rusty weathering	94' 6"
6	8'0"	Shale - medium blue grey, little silt, some orange-brown weathering, slightly less friable, somewhat bentonitic	102' 6"
5	3'0"	Shale - similar to above	105' 6"
	2'0"	Shale - similar to above	107' 6"
	0'5"	Bentonite - lower 2 inches grey-blue, upper 3 inches cream	107'11"
4	6'0"	Shale - medium blue-grey, little silt, somewhat friable, slightly bentonitic	113'11"
3	4'0"	Shale - medium grey, little silt, rusty and yellow weathering, somewhat platy, friable, selenite crystals	117'11"
2	1'0"	Shale - similar to above, sporadic ironstone concretions	118'11"
		<u>OLDMAN - BEARPAW CONTACT</u>	
1	2'0"	Shale - grey, intermixed with silt	

2. Bassano South: JW 66-17.
NE 6-20-18W4.
Elevation at base of section 2600 feet above sea level.
All sample weights 150 grams.

Sample No.	Interval	Lithology	Total Section
	16'0"	Sandstone - grey, bands of ochre-weathering material	
		BEARPAW - EDMONTON CONTACT	
	4'8"	Sandstone and some shale inter-beds - greyish-brown, carbon-aceous fragments	4' 8"
15	5'0"	Shale - greyish-brown, soft, rubbly, carbonaceous fragments, interbedded with buff silty clay	9' 8"
	0'6"	Ironstone concretionary band	10' 2"
14	2'0"	Shale - greyish-brown to dark grey, black speckled, some buff clay beds	12' 2"
	2'6"	Sandstone - light grey, thin lenses of iron-stained clay	14' 8"
	4'0"	Siltstone and sandstone - bands of grey sandstone with bands of greyish-brown shale and buff-brown silt	18' 8"
13	5'0"	Siltstone and sandstone - grey, some brown weathering	23' 8"
	1'0"	Bentonite - brownish-grey, some orange weathering, forms bench	24' 8"
12	6'6"	Shale - greyish-brown to dark grey, flaky, carbonaceous material, 1 inch hard brown ironstone clay band	31' 2"
11	6'0"	Shale - grey-brown, buff silty clay beds	37' 2"
10	6'0"	Shale - greyish-brown, fairly silty, carbonaceous material	43' 2"

Sample No.	Interval	Lithology	Total Section
9	6'0"	Shale - greyish-brown, fairly silty, carbonaceous material, one pelecypod	49' 2"
8	6'0"	Shale - brown, somewhat silty, carbonaceous fragments, buff silty clay beds present	55' 2"
7	6'0"	Shale - similar to above, possible weathered shell fragments, selenite crystals	61' 2"
		Moved section 200 feet south.	
	0'2"	Clay band - buff, silty	61' 4"
6	6'0"	Shale - greyish-brown, carbonaceous fragments, discontinuous ironstone concretionary band in upper 2 feet	67' 4"
5	6'0"	Shale - greyish-brown to dark grey, flaky to blocky, platy on fresh surface, carbonaceous material	73' 4"
4	5'6"	Shale - greyish-brown, carbonaceous material	78'10"
	0'6"	Double pale band of shells - pale brown weathering	79' 4"
3	6'0"	Shale - dark greyish-brown, fairly hard, somewhat silty, carbonaceous material	85' 4"
	0'2"	Band of shells - pale brown weathering	85' 6"
2	6'0"	Shale - similar to above	91' 6"
1	1'0"	Shale - similar to above	92' 6"
	0'5"	Sandstone - green, medium grained, very glauconitic	92'11"
X	below main sand	Shale - bluish-grey with some yellow weathering, nearly silt free, different from shale above main sand	

Sample No.	Interval	Lithology
Y	10 feet below X	Shale - dark grey to black, some mottling, possible carbonaceous fragments

3. Bassano: JW + MG 68-2A (JW 66-17).
NE 6-20-18W4.

Sample No.	Interval	Lithology
	30 feet above glauconitic sand	Shale - greyish-brown, carbonaceous fragments, silty

Bassano: JW + MG 68-2B (Cameron location 3).
Approximate elevation at river edge 2550 feet above sea level.

Sample No.	Interval	Lithology
	20 feet below massive sand	Shale - dark grey, some silt, brownish-grey weathering

Bassano: JW + MG 68-3 (Cameron location 1).
SE 24-19-18W4.
Elevation at base of section approximately 2500- feet above sea level.

Sample No.	Interval	Lithology
3	70 feet above river	Shale - dark grey, little silt, platy, rusty weathering
2	40 feet above river	Shale - brown grey, silty with silt lenses, rubbly, dark rusty weathering
1	20 feet above river	Shale - medium brown grey, silty, rusty weathering, blocky

4. East Coulee: MG 68-1.
NW 28-27-18W4.
Elevation at base of section 2221 feet above sea level.
All sample weights 150 grams.

Sample No.	Interval	Lithology	Total Section
		Sandstone - medium brown grey, medium grained, massive	
		BEARPAW - EDMONTON CONTACT	
	20'0"	Sandstone and siltstone - light grey brown, sand becoming dominant toward top of interval	20' 0"
4	8'0"	Shale - light brown grey, silty, carbonaceous fragments, quite friable, bentonitic, weathered rusty brown	28' 0"
3	6'0"	Shale - medium brown-grey, silty, platy, carbonaceous material, rusty weathering, bentonitic	34' 0"
2	6'0"	Shale - similar to above, some darker blue-grey shale bands with less silt	40' 0"
1	base of section	Shale - medium grey-brown, similar to above	

5. Dorothy: MG 68-3.
NE 33-26-17W4.
Elevation at base of section 2250 feet above sea level.
All sample weights 150 grams.

Sample No.	Interval	Lithology	Total Section
		Sandstone - light brown-grey, rusty brown weathering, medium grained	
		EDMONTON- BEARPAW CONTACT	

Sample No.	Interval	Lithology	Total Section
	10'0"	Sandstone and siltstone interbedded - medium brown, rusty weathering, sandstone becoming dominant toward top of interval	10' 0"
10	8'0"	Shale - medium brown, rubbly, silty, rusty weathering, bentonitic	18' 0"
9	20'0"	Shale and sandstone interbedded - medium brown-grey, rusty weathering, silty, bentonitic, sandstone beds becoming dominant toward top of interval	38' 0"
8	10'0"	Shale - medium brown-grey, silty, weathering lighter brown, rubbly, bentonitic, numerous sandstone bands up to 2 inches wide	48' 0"
7	8'0"	Shale - similar to above, less sand	56' 0"
6	8'0"	Shale - similar to above	64' 0"
5	8'0"	Shale - medium brown-grey, silty, rusty weathering, carbonaceous material common, bentonitic	72' 0"
4	1'0"	Shale - medium brown-grey, silty, carbonaceous fragments, bentonitic	73' 0"
	0'10"	Sandstone - brown-grey, medium grained, resistant, forms ledge	73'10"
	19'0"	Sandstone and siltstone interbedded - medium brown-grey, sand is dominant	92'10"
3	15'0"	Shale - medium brown, very sandy, blocky, rusty weathering, bentonitic, numerous sandstone bands up to 18 inches	107'10"
	0'2"	Ironstone concretion band	108' 0"

Sample No.	Interval	Lithology	Total Section
2	3'0"	Shale - medium brown-grey, silty, carbonaceous fragments, platy, bentonitic	111' 0"
1	above bentonite	Shale - medium brown-grey, silty, carbonaceous fragments, blocky, bentonitic	
		"DOROTHY BENTONITE" TOP	
	30'0"	Bentonite - grey-green, weathering blue-grey	141' 0"
11	?10'0" (slump)	Shale - grey-brown, rubbly, some fine dark shale flakes intermixed	151' 0"
12	7'0"	Shale - dark grey, yellow weathering, sandy	158' 0"
13	10'0"	Shale - dark grey, silty, rusty weathering	168' 0"
14	10'0"	Shale - dark grey, rubbly, sandier toward base of interval	178' 0"
		"DOROTHY SANDSTONE" TOP	
	15'0"+	Sandstone - brown-grey, massive, ledge-forming, medium to coarse grained, glauconitic, bentonitic	193' 0"+

Dorothy: MG 68-4.
SW 26-26-17W4.
Elevation at base of section 2200 feet above sea level.
All sample weights 150 grams.

Sample No.	Interval	Lithology	Total Section
		"DOROTHY SANDSTONE" TOP	
	20'0"	Sandstone - brown-grey, medium to coarse grained, massive, forms ledge, glauconitic, bentonitic	20' 0"

Sample No.	Interval	Lithology	Total Section
8	4'0"	Shale - dark blue grey, inter-bedded with silty and sandy bands	24' 0"
7	5'0"	Shale - dark blue grey, some silty laminae, sandy	29' 0"
6	5'0"	Shale - dark blue grey, some silt and sand bands	34' 0"
5	5'0"	Shale - similar to above	39' 0"
4	1'0"	Shale - similar to above	40' 0"
	0'6"	Sandstone - medium brown-grey, coarse grained, forms small ledge	40' 6"
3	1'0"	Shale - dark blue-grey, similar to above	41' 6"
2	4'6"	Shale - dark blue-grey, sandy, some silty bands, yellow weathering	46' 0"
1	river edge	Shale - dark blue-grey, some silty bands, sandy, rusty weathering	

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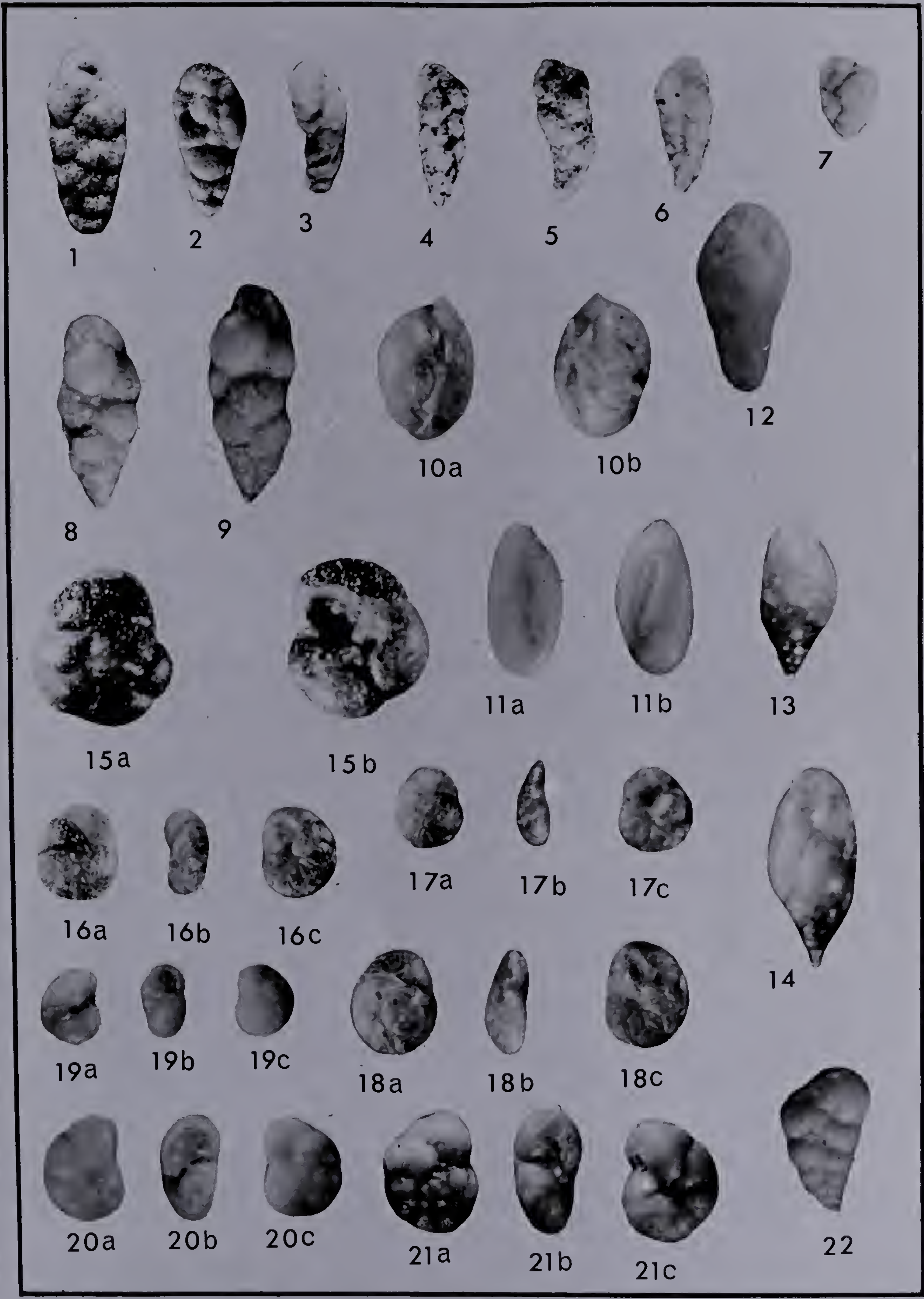
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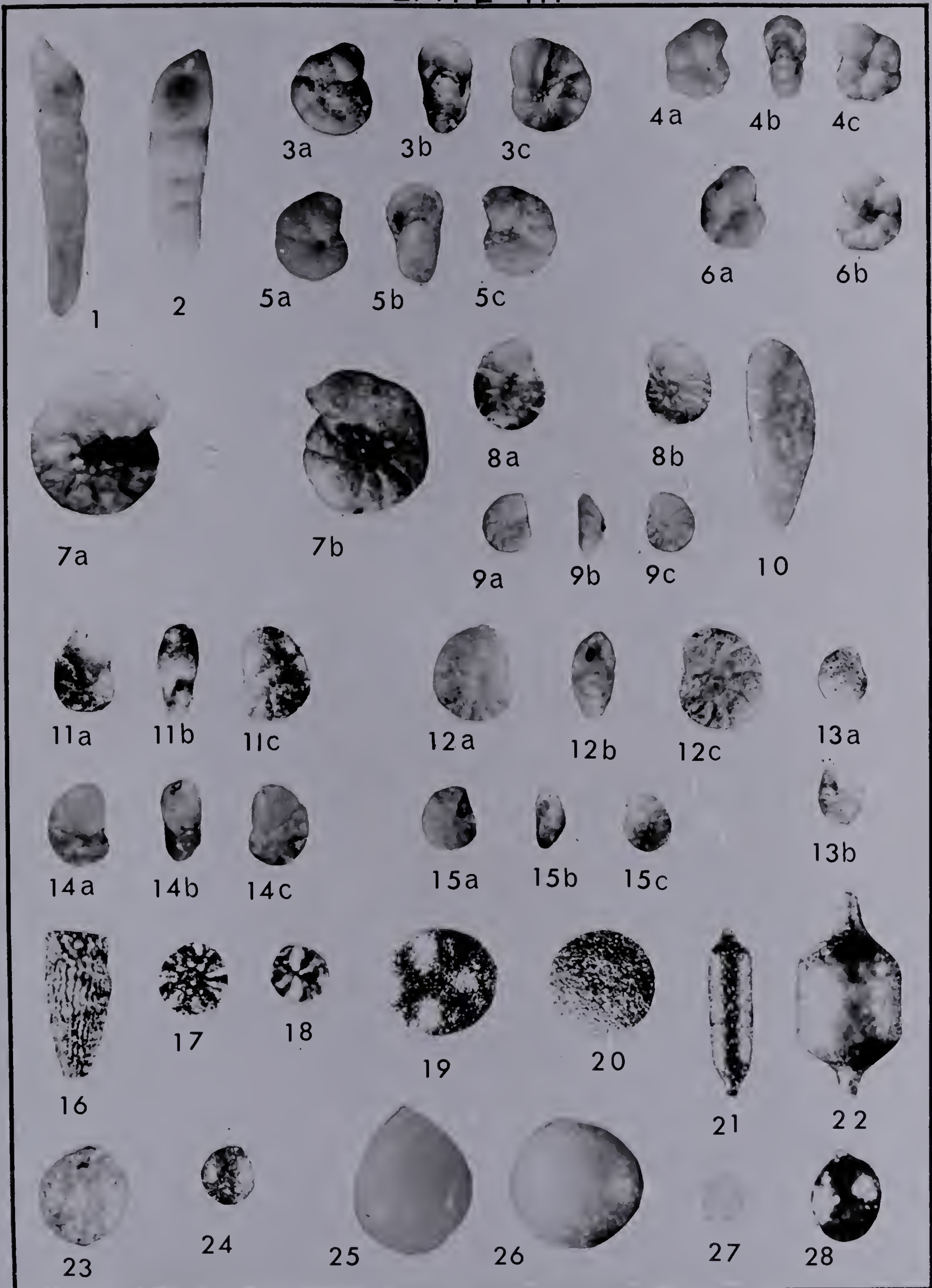
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